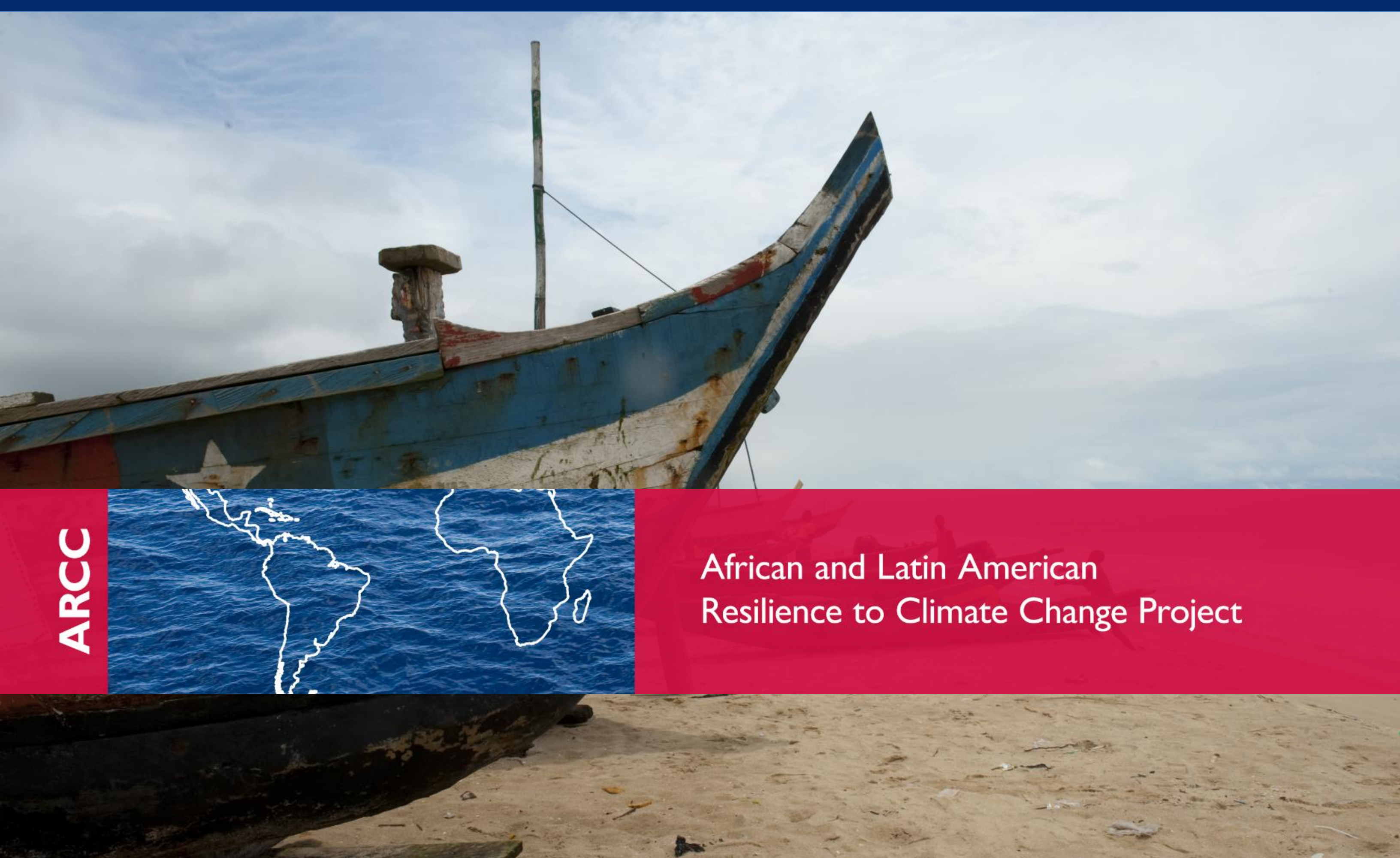
CLIMATE CHANGE AND WATER RESOURCES IN WEST AFRICA: COASTAL BIOPHYSICAL AND INSTITUTIONAL ANALYSIS

JULY 2014

This report is made possible by the support of the American people through the U.S. Agency for International Development (USAID). The contents are the sole responsibility of Tetra Tech ARD and do not necessarily reflect the views of USAID or the U.S. Government.



Contributors to this report, in alphabetical order: Marie-Caroline Badjeck[1], Bill Bohn[2], and Matt Sommerville[2].

[1] Independent consultant

[2] Tetra Tech Inc.

Cover Photo: Nigerian fishing boats. Courtesy of World Bank

This publication was produced for the United States Agency for International Development by Tetra Tech ARD, through a Task Order under the Prosperity, Livelihoods, and Conserving Ecosystems (PLACE) Indefinite Quantity Contract Core Task Order (USAID Contract No. AID-EPP-I-00-06-00008, Order Number AID-OAA-TO-11-00064).

Tetra Tech ARD Contacts:

Patricia Caffrey
Chief of Party
African and Latin American Resilience to Climate Change (ARCC)
Burlington, Vermont
Tel.: 802.658.3890
Patricia.Caffrey@tetratech.com

Anna Farmer
Project Manager
Burlington, Vermont
Tel.: 802.658.3890
Anna.Farmer@tetratech.com

CLIMATE CHANGE AND WATER RESOURCES IN WEST AFRICA:

COASTAL BIOPHYSICAL AND INSTITUTIONAL ANALYSIS

AFRICAN AND LATIN AMERICAN RESILIENCE TO CLIMATE CHANGE (ARCC)

JULY 2014

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

ACMAD	African Center of Meteorological Application for Development
AGRHYMET	AGRrometeorology, HYdrology, METeorology Regional Center
AMESD	African Monitoring of Environment for Sustainable Development
AMMA	African Monsoon Multidisciplinary Analysis
ARCC	African and Latin American Resilience to Climate Change
CCLME	Canary Current Large Marine Ecosystem
CILSS	Permanent Interstate Committee for Drought Control in the Sahel
CSE	*Centre Suivi d'Ecologique*
CZCP	Coastal Zone Community of Practice
DFID	Department for International Development
ECOWAS	Economic Commission for West African States
EEZ	Exclusive Economic Zone
FAO	Food and Agriculture Organization of the United Nations
FFP	Fund for Peace
GCC	Guinea Current Commission
GCLME	Guinea Current Large Marine Ecosystem
GEF	Global Environment Facility
GEO	Group on Earth Observations
GFCS	Global Framework for Climate Services
GOOS	Global Ocean Observing System
IDRC	International Development Research Center
IFPRI	International Food Policy Research Institute
IGCC	Interim Guinea Current Commission
IISD	International Institute for Sustainable Development
IOC	Indian Ocean Commission
IODE	International Oceanographic Data and Information Exchange
IPCC	Intergovernmental Panel on Climate Change
ISRA	Senegalese Agricultural Research Institute

IUCN	International Union for Conservation of Nature
IUU	Illegal, Unreported, and Unregulated Fishing
LDCF	Least Developed Countries Fund
LOE	Level of Effort
LME	Large Marine Ecosystem
NEPAD	New Partnership for Africa's Development
NOAA	U.S. National Oceanographic and Atmospheric Administration
OLOA	West Africa Coastal Observatory
ODINAFRICA	Ocean Data and Information Network for Africa
ORSTOM	French Institute of Scientific Research for Development in Cooperation
SAP	Strategic Action Program
SHOM	*Service Hydrographique et Océanographique de la Marine* (Naval Hydrographic and Oceanographic Service)
SLR	Sea-Level Rise
SRES	Special Report on Emissions Scenarios
SST	Sea Surface Temperature
UEMOA	West African Economic and Monetary Union
UN	United Nations
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
WAMS	World Association of Marine Stations
WASCAL	West African Science Service Center on Climate Change and Adapted Land Use
WMO	World Meteorological Organization
WWF	World Wide Fund for Nature

ABOUT THIS SERIES

THE STUDIES ON CLIMATE CHANGE VULNERABILITY AND ADAPTATION IN WEST AFRICA

This document is part of a series of studies produced by the African and Latin American Resilience to Climate Change (ARCC) project that address adaptation to climate change in West Africa. Within the ARCC West Africa studies, this document falls in the subseries on Climate Change and Water Resources in West Africa. ARCC has also developed a subseries on Agricultural Adaptation to Climate Change in the Sahel, Climate Change and Conflict in West Africa, and Climate Change in Mali.

THE SUBSERIES ON CLIMATE CHANGE AND WATER RESOURCES

Upon the request of the United States Agency for International Development (USAID), ARCC undertook the West Africa water studies to increase understanding of the potential impacts of climate change on water resources in West Africa and to identify means to support adaptation to these changes. Other documents in the climate change and water resources in West Africa series include: Transboundary River Basins, Mapping the Exposure of Socioeconomic and Natural Systems of West Africa to Coastal Climate Stressors, and an Assessment of Groundwater Management.

EXECUTIVE SUMMARY

Climate change is placing new, unanticipated pressures on West African coasts, areas that are already experiencing stressed ecological systems and rapidly changing socioeconomic dynamics. At present, the pressures of urban development, rush for resources, and challenges of carrying out and enforcing land-use planning dominate development along the coast. The lens of climate change offers the opportunity to integrate medium- and long-term risk into coastal planning and development. This desk-based assessment documents the current state of knowledge and key information gaps on the impacts of climate change on social and biophysical systems of West Africa. It then assesses regional institutions for their adaptive capacity to help countries adapt to climate impacts. Finally, the report outlines areas for potential engagement for additional research and scoping on West African coastal climate impacts.

SOCIAL AND BIOPHYSICAL COASTAL IMPACTS OF CLIMATE CHANGE

Climate Observations and Modeling: Over recent decades, efforts to build a base of information on climate change impacts and future projections in West Africa have focused on the Sahel. Much less attention has been given to understanding coastal climate processes in the region, despite global interest in coastal climate impacts. As a result, many of the assumptions about coastal hazards in West Africa are based on global patterns or analogues from other parts of the world. There are specific gaps in understanding and analyzing how the variety of climate impacts in the coastal zone will change in West Africa – from sea level rise to increased extreme events to changes in temperature and precipitation. Because the coastal morphology and siting of important economic infrastructure varies so significantly across the thousands of kilometers of coastline, and because the impacts of climate change depend on how climate interacts with these variables, it is not possible to generalize West African coastal vulnerabilities. This assessment therefore raises some red flags around vulnerable areas, but localized analyses are necessary.

Coastal Erosion: The primary limitation in the understanding of coastal erosion is the lack of coastal geomorphology profiles and lack of data on coastal assets that will impact and be impacted by erosion. The new littoral observation network that is currently being established for the region at the *Centre de Suivi Ecologique* in Senegal will be an important step in the right direction for systematically identifying vulnerability to erosion. Despite this positive development isolating the relative impact of climate change on coastal erosion, there remains a controversial and unresolved scientific discussion on the causes of coastal erosion. Yet irrespective of the causes, erosion is a crucial concern that coastal managers will continue to attempt to mitigate at a national and regional level.

Coastal Wetlands, Including Mangroves and Deltas: These ecosystems are likely to be the most vulnerable to climate change in West Africa, and they are facing immense threats from non-climate drivers, as well. In these cases, sea-level rise is interacting with coastal erosion and accretion. Migratory birds that depend on these wetlands are particularly vulnerable, and more in-depth hydrological and ecological modeling of West African river deltas, including socioeconomic threats and drivers, is necessary.

Fisheries: Fisheries are perhaps the transboundary sector most clearly impacted by climate change, and while the theoretical basis for fisheries impacts from climate change are well described, our ability to project how these impacts will influence West African fisheries is extremely limited. Lessons can be learned from how increased understanding of migratory patterns has influenced regulation of fisheries by states in the U.S., but the challenge of regional coordination and enforcement of illegal, unregulated, and unreported fisheries in West Africa will remain a significant barrier to integrating climate change into regional fisheries management. Climate change impacts on lagoon and mangrove fisheries is also likely to be significant, with warmer shallow waters interacting with increased nutrient flow in the river deltas. Eutrophication events could lead to major die-offs impacting local food security. Investment in these coastal fisheries must consider this vulnerability.

Crops: The impacts of climate change on crops in West Africa has primarily focused on the grains and cash crops of the Sahel. Recent work by the International Food Policy Research Institute has tried to build a greater understanding of climate impacts across all West African nations on crop productivity. While regional crop production is expected to increase under climate and technological change predictions, areas within countries are expected to respond in different ways. Crop modeling on coastal tree crops of cocoa, coffee, rubber, and oil palm are needed to better understand how this important economic sector will respond over coming decades. At present, the data on these tree crop responses to climate impacts in West Africa is sporadic and country-specific. However, the expansion of this analysis is limited by poor understanding of coastal soils across West Africa.

Urban and Peri-Urban Cases: Coastal urban areas are particularly vulnerable to climate change impacts, and while sector-specific risks can be generalized, each urban area has its own biophysical and socioeconomic dynamics that govern vulnerability. Long-lasting infrastructure in urban areas leads to high levels of risk, and there are often pressures to use all available land for economic purposes. Additionally, the high value of infrastructure and high populations mean that a climate-related impact will have larger economic and humans costs than impacts in rural coastal areas. And while in many cases these urban and peri-urban areas have more resources to dedicate to adaptation than rural areas, they may still be prone to destabilizing climate impacts.

Specific knowledge and action gaps in urban areas include investment in: city-specific vulnerability assessments for West African urban areas that assess vulnerable infrastructure, services, and populations; multi-stakeholder processes to understand the risks facing large coastal investments and peri-urban poor; and opportunities for municipalities to share their planning experiences regionally. This is particularly important as most West African countries have one single coastal megacity, and therefore opportunities for sharing lessons about urban planning within individual countries may be limited.

ANALYSIS OF ADAPTIVE CAPACITY OF COASTAL ZONE INSTITUTIONS

Effective climate adaptation at a national level requires governments and their partners to: undertake assessments; prioritize impacts and options; develop and coordinate policy; implement policy and programs; and manage the information generated in an adaptive management cycle. All of these capacities are rarely, if ever, housed in a single institution in any country, including in developed economies. As a result, institutions from government, civil society, academia, and the private sector will have to find mechanisms to coordinate and support one another to fill these capacities. This assessment examined the capacity of West African, regional, and global institutions to fill these capacities in West Africa, and while national institutions were briefly considered, many capacities were undoubtedly overlooked. The scope of the assessment did not provide adequate time or resources to assess national institutions independently across all of the West African countries.

Nevertheless, across West Africa the relationship between information-generating institutions and policy and implementation is particularly weak. In many countries, specific core capacities are missing or housed in a few individuals rather than in robust institutions.

On Assessment: There are a number of global institutions monitoring West African oceans; however to date, these have not translated into increased research or information on climate impacts on the West African coastal zone. At the same time, regional climate change institutions like

AGRrometeorology, HYdrology, METeorologyRegional Center (AGRHYMET) and African Center of Meteorological Application for Development (ACMAD) have not considered coastal zone impacts of climate change. There is an institutional gap waiting to be filled to provide regionally relevant information on climate change impacts and potential climate services on the coast. Yet, coastal zone assessments of climate vulnerability are particularly prone to mission creep and it is challenging but necessary to target assessments on specific sectors, locations, and impacts, in part because it is likely that new primary data may be necessary to collect.

On Prioritization, Policy Development, and Coordination: At the regional level, there are viable institutions to lead in policy development and coordination, particularly the Economic Commission for West African States (ECOWAS). The Guinea Current Commission and the Guinea Current Large Marine Ecosystem (GCLME) may be particularly well-suited to fill this policy role, but it remains to be seen whether the GCLME will continue to be run like a long-term project of the United Nations (UN), or whether it will become a stand-alone institution. The primary constraint of ECOWAS, other regional policy institutions, and to some extent the GCLME is that their policy/environment teams, while well-qualified and covering a range of environmental issues, are very small. A further constraint of climate change considerations within these regional organizations, and subsequently national governments, is that climate change is relegated to the environment ministry, which is often among the politically weakest ministries in government.

On Implementation: Despite the preparation of a series of national-level climate change planning documents, and the prioritization of coastal zone issues in discussions of climate change, implementation of planned projects has been largely nonexistent in most West African countries. Isolated pilot projects have been launched in roughly half of coastal countries, but these remain the exception. West African institutional capacity largely rests in Nigeria, Ghana, and Senegal, with individual experts operating independently in many other West African countries.

On Information Management: There are numerous regional and national institutions collecting and managing information relevant to climate change adaptation in West Africa. Yet coordination and coherent information management related to climate change faces significant uphill battles because of the broad variety of sectors involved in coastal zone management. In the short-term, it is necessary to ensure that ECOWAS and other regional political institutions continue to create space for the sharing of information until a critical mass builds to support communities of practices around climate change and specific coastal issues.

RECOMMENDATIONS

This report identified four priority areas for engagement on coastal zone adaptation related to: **urban centers; mangrove areas; climate information and services;** and **coastal fisheries**. Coastal erosion was also a priority identified by numerous actors, but there is an emerging erosion-monitoring and -research facility under development, the *Observatoire du Littoral Ouest Africain*, and as a result, it is a gap that is being filled.

Priority research should focus on the implementation of **urban vulnerability assessments and processes to integrate climate change into West African urban planning**. These assessments are not regional; however, because most countries have a single urban coastal mega-city, there will be a need to share experiences and learn regionally.

Climate change and mangroves surrounding river deltas is an important area for research. These efforts could fit into the Mangrove Charter and National Action Plan for West Africa by supporting efforts to restore and conserve mangrove belts. Regional collaboration could also be achieved through work with the Food and Agricultural Organization (FAO) of the UN on sustainable fuel production in coastal zones for salting and smoking fish.

Some early warning systems for coastal disasters do exist, such as well-developed tsunami warning systems for ocean basins and regional coastal flooding systems, primarily in developed countries. Globally, however, climate services for coastal zones are underdeveloped. West Africa provides an interesting laboratory for exploring the role of coastal climate services and piloting delivery of services across a variety of countries. One of the primary challenges of climate services is reaching affected populations. Different West African countries will have different approaches for providing information and engaging with their coastal communities. This provides an interesting laboratory for pilot activities in a variety of countries to contrast the effectiveness of a variety of private- or public-sector-led approaches to reaching communities with coastal climate service information.

Nearshore and marine fisheries are undoubtedly impacted by changing climate, and yet the climate impacts on particular species and ecosystems are poorly understood. Local fisheries impact assessments building on USAID work on coastal fisheries in West Africa is potentially interesting, but should likely be done through active collaboration with the U.S. National Oceanographic and Atmospheric Administration (NOAA), which is already considering these applied research questions on various fisheries around the world. Aquaculture planning will be particularly impacted by climate information. Climate-resilient community aquaculture has been explored internationally and elements of this work could be brought into future USAID coastal zone investments. Deeper research on this topic could be undertaken by an international aquaculture expert leading a team of national researchers in countries with significant or growing aquaculture interests.

Across each of these entry points, there is a need to support **core capacities in academic research** on coastal zones (including but not limited to climate change), as well as building the capacity of **local-level extension agents** and **regional implementers** to understand and respond to climate change.

1.0 INTRODUCTION

The highly populated coastal zone of West Africa is one of the areas in the world most vulnerable to climate change (IPCC, 2007). Climate change will impact the area's coastal ecosystems as well as its socioeconomic environment. Consideration of climate change and climate variability affects how we plan and react to development challenges, particularly in decision-making that is expected to be robust in the long-term. In West Africa, sea-level rise, increased temperatures, storms, and ocean acidification — coupled with the current stressors of political turmoil, poverty, forced migration, public health, and education challenges — create a challenging environment for successful adaptation across a variety of economic sectors. It is thus appropriate to examine projected climate change impacts on the coastal zone and in sectors where USAID is active, and consider opportunities for USAID to build resilience into its programming.

FIGURE 1. REGIONAL MAP OF WEST AFRICA

The purpose of this report is to:

1. Assess current knowledge concerning the impacts of climate change on ecosystems and livelihoods in West African coastal zones;
2. Identify knowledge gaps for future work;
3. Identify the sector and geographic hotspots where climate change is expected to have the largest impact;
4. Assess the mandate and capacity of regional institutions to respond to climate change and coastal management challenges; and
5. Identify opportunities and inform USAID support to regional institutions charged with managing the impacts of climate change on the West African coast.

The report starts by describing the current state of knowledge on climate change projections in West Africa, and the use of these projections and other information in assessing vulnerability. This is followed by an institutional analysis of regional capacity to respond to adaptation challenges and a summary of key gaps and recommendations for future research.

For the purposes of this report, countries constituting the West Africa area include: Benin, Cameroon, Cape Verde, Cote D'Ivoire, the Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Nigeria, Senegal, Sierra Leone, and Togo (pictured in Figure 1).

1.1 BACKGROUND

1.1.1 West African Reliance on the Coast

Forty percent of the West African population lives in coastal cities, and by 2020, more than 500 kilometers of coastline between Accra and the Niger delta is projected to develop into a continuous urban megalopolis of more than 50 million inhabitants (Hewawasam, 2002). In Nigeria, approximately 20 million people (22.6 percent of the national population) already live along the coastal zone; in Senegal, approximately 4.5 million people (66.6 percent of the national population) live in the Dakar coastal area, along with 90 percent of the industries; and in Ghana, Benin, Togo, Sierra Leone, and Nigeria, most of the economic activities are located within the coastal zone. For this report, the coastal zone is broadly defined as dry land and adjacent ocean space (water and submerged land) in which terrestrial processes and land uses directly affect oceanic processes and uses, and vice versa (Ketchum, 1972). Coastal areas in West Africa also form the food basket of the region. Fisheries in the West African Marine Eco-Region generate $400 million annually, making them the single most important source of foreign exchange in the region and a key source of revenue for economic and social development (WWF, 2013).

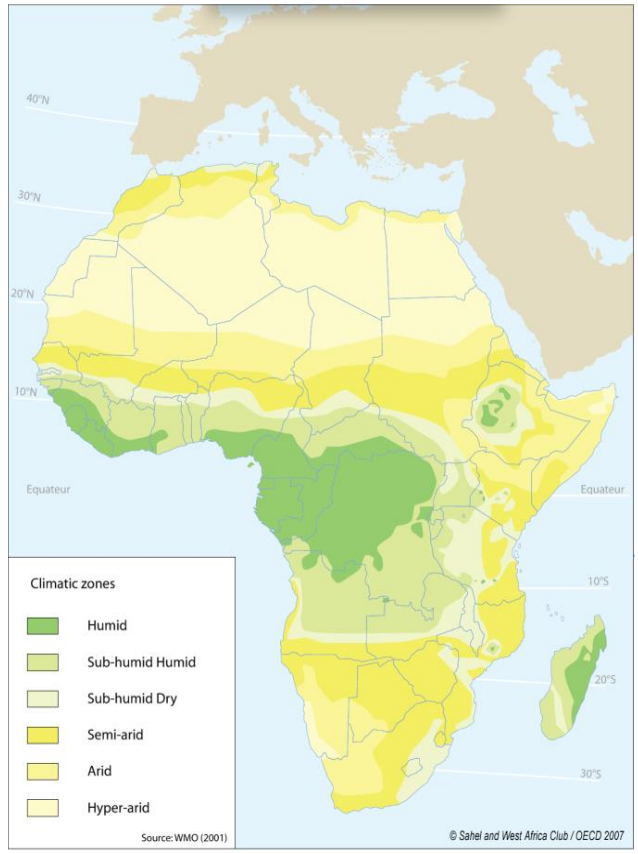
West Africa's natural environment is dependent on an upwelling of nutrients into the warm, shallow seas that mark the Sahara's embrace of Atlantic swells. More than 1,000 fish species have been surveyed in a variety of habitats, including estuaries, mangroves, sandy beaches, mudflats, and sea-grass beds. Other species found in this region include the critically endangered monk seal and vulnerable West African manatee, as well as crocodiles, whales, dolphins, sharks, and rays. The area also provides a home for a variety of birds.

1.1.2 West African Instability

West Africa's political instability and governance issues will present adaptation challenges for several countries. Over the past year (2012 to 2013), a variety of destabilizing events took place, including a coup d'état in Mali on March 22, 2012; a coup in Guinea-Bissau on April 12, 2012; armed insurrection and instability in Côte d'Ivoire; piracy in the Gulf of Guinea; and increased illicit drug trafficking and terrorists threats to the region. While introducing the secretary general's report on the United Nations Office for West Africa, Special Representative Said Djinnit stated that West Africa remains "precarious and [its success is] reversible, as the root causes of instability are yet to be fully addressed." The 2013 Failed States Index created by the Fund for Peace (FFP) identified four West African countries in the alert/warning category and three in the warning category. Individual country ranking in the 2013 index is noted in parenthesis as follows (FFP, 2013):

1. **Alert/Warning:** Cote D'Ivoire (12), Guinea (14), Guinea Bissau (15), and Nigeria (16)
2. **Warning:** Liberia (23), Cameroon (27), Sierra Leone (33), Togo (42), the Gambia (62), Senegal (64), Benin (78), Cape Verde (94)
3. **Stable:** Ghana (110)

FIGURE 2. WEST AFRICAN CLIMATIC ZONES



1.1.3 Climate Patterns

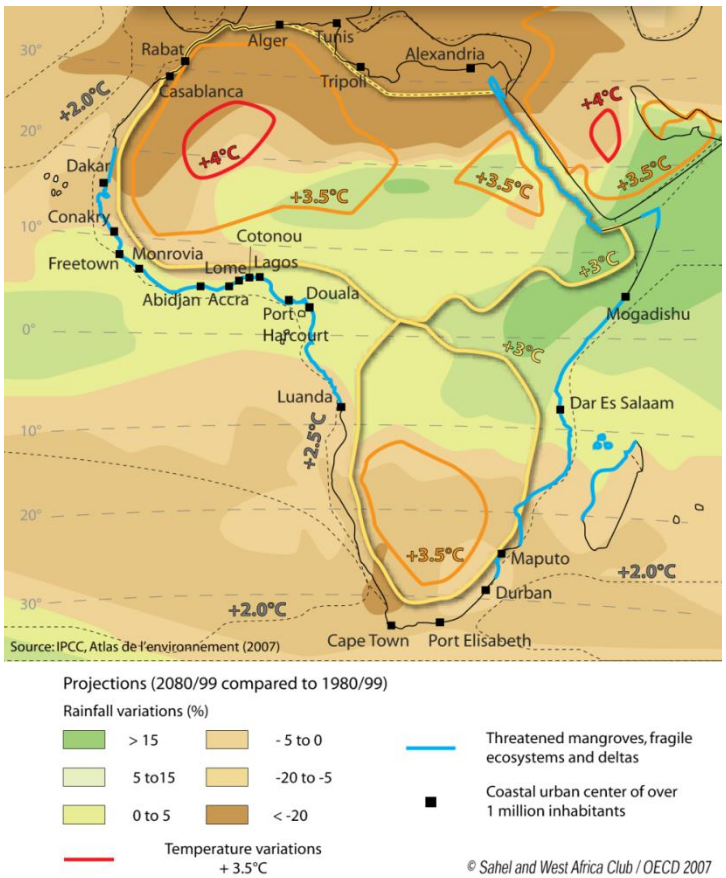
Most of the African continent is tropical, except for the Mediterranean region and South Africa. There is little variation in the temperature throughout the year, although the temperature differences between daytime and nighttime can be as much as 10 to 15°C or higher in deserts. Inter-annual variations south of the Sahara are between 6 and 10°C. Figure 2 shows the current climatic zones in Africa. Coastal West Africa includes four of these six zones: 1) a semi-arid zone in Senegal; 2) a sub-humid dry zone in Senegal and the Gambia; 3) a sub-humid humid zone in Cape Verde, Guinea-Bissau, Ghana, Togo, and Benin; and 4) a humid zone in Guinea, Sierra Leone, Liberia, Cote d'Ivoire, Nigeria, and Cameroon.

Rainfall patterns in West Africa are driven by the seasonal movement of the inter-tropical convergence zone, where the hot and dry tropical easterly winds blowing in from the northeast meet with the humid air masses coming in from the southern Atlantic Ocean, bringing on the monsoon season. The semi-arid zone, including the Sahel and Sahel-Saharan belt, consists of a single rainy season. The Sahel receives most of its rainfall between July and September. The rainfall patterns in the Gulf of Guinea countries consist of two rainy seasons and two dry seasons. West Africa's climate is subject to considerable variability, particularly in the Sahel, where rainfall varies by more than 1,000 millimeters over a distance of 750 kilometers. This region is very sensitive to changes of the inter-tropical convergence zone, and the rainfall season can fluctuate up to 30 percent in length.

Over the last fifty years, there has been a substantial reduction in rainfall in West Africa. In the Sahel, this reduction is extremely clear with high-deficit periods in 1972–73, 1982–84, and 1997. This recent trend has taken the form of reduced rainfall over a 200-kilometer distance towards the south and an aridification process in the region (Sahel and West Africa Club, 2006). This decrease in rainfall has been seen in the Gulf of Guinea areas, as well. Although rainfall conditions have increased since the mid-1990s, the rainfall patterns seen decades beforehand may return.

2.0 CLIMATE CHANGE IN WEST AFRICA

FIGURE 3. TEMPERATURE AND RAINFALL PROJECTIONS FOR AFRICA OVER THE 21ST CENTURY



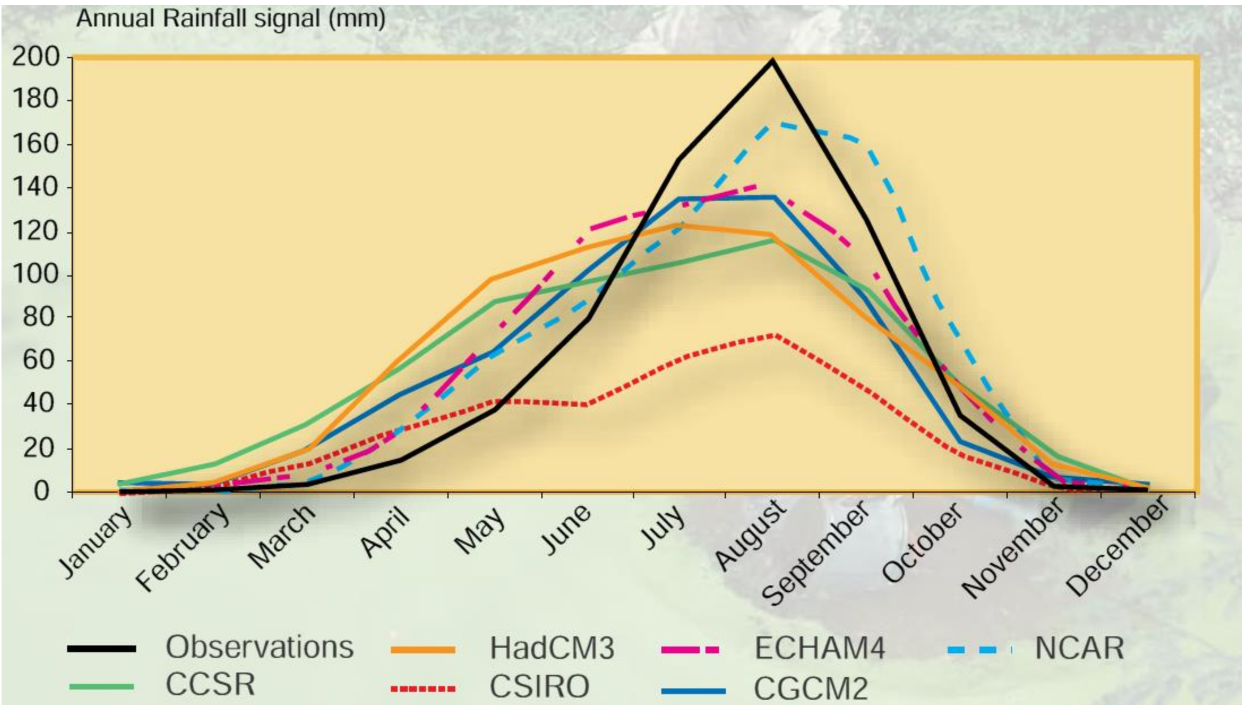
This chapter briefly presents the current state of climate science in West Africa related to temperature, rainfall, extreme events, ocean pH and sea-level rise.[1] Subsequent chapters consider how these changes are likely to impact physical, social, and biological systems of West Africa. According to the Intergovernmental Panel on Climate Change (IPCC), West Africa is very likely to warm during the 21st century. This warming in Africa is likely to occur during all seasons and is very likely to be larger than the global, annual mean warming, with drier subtropical regions warming more than the moister tropics (IPCC, 2007). There is great uncertainty concerning rainfall in the Sahel, the Guinean Coast, and the southern Sahara due to the significant systematic errors of the climate models in the region. The absence of realistic variability in the Sahel in most 20th-century simulations for rainfall casts doubt on the reliability of coupled atmospheric-ocean models in this region (IPCC, 2007).

---

[1] For a more complete treatment of this topic, see the *Background Paper for the ARCC West Africa Regional Climate Change Vulnerability Assessment*, USAID, 2013.

Temperature: Climate models are in general agreement when predicting temperature changes for Africa. West Africa has experienced significant warming over the recent decades (faster than the rest of the world), particularly in the Sahel. This trend is stronger for minimum temperatures than maximum temperatures. The average rise in temperature between 1980–1999 and 2080–2099 is expected to be between 3 and 4°C for the continent. These changes would be one and a half times greater than at the global level. Figure 3 shows projected temperature changes for the continent. While increases are expected to be highest in the Western Sahara (+4°C), they are smallest in the coastal and equatorial areas (+3°C) under consideration in this study.

FIGURE 4. MODEL PERFORMANCE AT PREDICTING OBSERVED RAINFALL IN THE SAHEL BETWEEN 1961 AND 1990

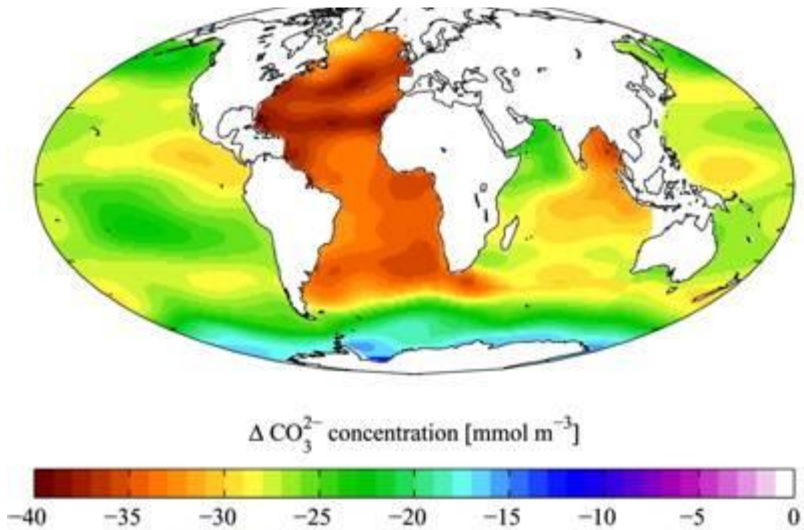


Source: Capacity building project for adaptation to climate change in the Sahel, CRA / CILSS (to be published)

Rainfall: Predicting future rainfall has been more difficult than predicting temperature, so projections remain more uncertain. Climate models show a decrease in precipitation (-15 to -20 percent) over this century for Africa's coastline from the Mediterranean down to Dakar. Figure 3 shows the projected rainfall change for Africa over the 21st century.

The uncertainty in rainfall-related climate projections for West Africa can be seen by averaging all the scenarios for the region. This average shows slight humidification in the Sahel region, with no real changes along the Guinean coast. Recent tests have shown the limited capacity of current models to forecast West Africa's climate (Kamga, 2006). The models show the start of the rainy season one to two months before the rainy season actually occurs. Comparing the observed climate in the Sahel from 1961 to 1990 to climates simulated by six general circulation models recommended by the IPCC over the same period (see Figure 4) illustrates these shortcomings. The models are unable to predict the start of the rainy season and tend to over predict rainfall in the months prior to the rainy season. A considerable bias (140 to 215 millimeters/year) in annual aggregate rainfall estimates compared to the observed rainfall (the solid black line) can also be seen in Figure 4. The Atlantic and Indian Ocean water temperature changes and temperature anomalies in the Pacific, linked to the El Niño phenomenon, are an important driving force for West Africa's monsoon activity. Temperature variations in the oceans, which are sensitive to global climate changes, will impact the West African monsoon. These global phenomena are further impacted by continental surface processes (vegetation, soil moisture, and water cycle on monsoon dynamics). The interactions between these continental dynamics and the climate are not sufficiently understood to effectively project coastal precipitation with any certainty.

FIGURE 5. GLOBAL OCEANIC CARBON DIOXIDE CONCENTRATIONS



Extreme Events: The IPCC acknowledges the limitations of research on extreme climate events in West Africa. Even with these limitations, it is thought that the frequency and severity of floods and droughts in areas with high rainfall variability are likely to increase. In recent assessments of the potential flood risks that may arise by 2080 across a range of emission scenarios and climate change projections, three of the five regions shown to be at risk of flooding and storm surge from extreme events in coastal and deltaic areas of the world are those located in Africa: North Africa, West Africa, and southern Africa (Nicholls and Tol, 2006; for more detailed assessments, see Warren et al., 2006).

Oceanic Carbon Dioxide Concentrations: Increasing atmospheric carbon dioxide (CO_2) concentrations and lowering oceanic pH and carbonate ion concentrations will decrease the atmosphere's saturation state with respect to calcium carbonate (Feely et al., 2004). Currently, surface ocean pH is already 0.1 unit lower than pre-industrial values. In the median estimate of the multi-model, pH is projected to decrease by another 0.3 to 0.4 units under the IPCC IS92a scenario by 2100. This translates into a 100- to 150-percent increase in the concentration of H+ ions (Orr et al., 2005) and a corresponding decrease in carbonate ion concentrations (Figure 5). When water is under-saturated with calcium carbonate, marine organisms can no longer form calcium carbonate shells (Raven et al., 2005). The IPCC forecasts that ocean pH will fall by "between 0.14 and 0.35 units over the 21st century, adding to the present fall of 0.1 units since pre-industrial times" (IPCC, 2007). In coastal areas, unlike in the open ocean, CO_2 can come from both land and air, amplifying acidification in focal hotspots where land and water meet.

Sea-Level Rise (SLR): Increased temperatures are causing ocean levels to rise, due to thermal expansion of water and land-based ice melt. Worldwide estimates for the end-of-century timeframe (2090 to 2099) IPCC 4th Assessment Report climate scenario show a sea-level increase of 18 to 38 centimeters for an increase of 2 °C, and a 26- to 59-centimeter increase for an increase of 4 °C to the atmospheric temperature (IPCC, 2007). Other recent sea-level rise estimates predict that the AR4 projects may be underestimating the magnitude of the change (Good et al., 2011).

From 1950 to 2009, the average annual rise in recorded sea level was 1.7 (±0.3) millimeters per year, with satellite data showing a rise of 3.3 (±0.4) millimeters per year from 1993 to 2009. The sea-level rise estimates above do not include the full effects of changes in ice-sheet flow and uncertainties regarding climate-carbon cycle feedbacks. Recent USNRC projections indicate a rise from 56 to 200 centimeters by the end of the 21st century (USNRC, 2010).

To better understand sea-level rise projections at the regional and local levels, the worldwide models need to be integrated with local sea-level rise trends. Tidal data has been collected from seven gauges along the West African coast. This data is used to develop local trends and is more accurate with longer and complete temporal records. Several of the tidal gauges have temporal data gaps, which are common in the southern hemisphere; more complete, longer term, continuous tidal records are generally available for North America, Europe, and Northern Asia. Recent efforts by the University of La Rochelle, the United Nations Educational, Scientific, and Cultural Organization (UNESCO), and the *Service Hydrographique et Océanographique de la Marine* (Naval Hydrographic and Oceanographic Service, SHOM) have attempted create a 100-year time series reconstruction for Dakar based on data from SHOM, French Institute of Scientific Research for Development in Cooperation (ORSTOM), NOAA, and the University of Hawaii. The results of the study indicate a trend of 1.41 (±0.20) millimeters of sea-level rise per year, which is consistent with global averages.

Rising sea levels will impact all West African countries (though to varying degrees depending on each country's coastal environment), exacerbating coastal erosion rates. Over time, this will result in a greater number of people being exposed to chronic and episodic disasters, such as loss of coastal homes and land, loss of wetland aquaculture areas, saltwater intrusion impacts to drinking water, and loss of inland homes that are within extended flood zones. While data on actual impacts in West Africa are quite sparse, one study indicates sea-level rise impacts for West African coastal countries (Table 1).

TABLE 1. IMPACTS OF CLIMATE CHANGE ON THE COASTAL ZONES OF AFRICA

Country	Area at Risk (square kilometer)	People Affected	Economic Value at Risk ($M)
Cape Verde	NA	100	33.7
Senegal	6,042–6,073	109,000–78,000	499–707
Gambia	92	42,000	217
Guinea-Bissau	NA	1,600	34.7
Guinea	289–468	500,000	NA
Sierra Leone	NA	26,000–1,220,000	5,860
Liberia	NA	NA	NA
Cote d'Ivoire	NA	NA	NA
Ghana	NA	NA	NA
Togo	NA	NA	NA
Benin	230	1,350,000	118
Nigeria	250	3,200,000	18,000
Cameroon	NA	2,300	619.7

Note: NA reflects information Not Available. Source: Niang-Diop, 2005

Knowledge Gaps: Currently, there is relatively strong agreement on temperature increases in West Africa, but much less agreement on precipitation. In order to understand rainfall patterns, appropriate equipment is needed to monitor and record weather systems in the region.

The AGRHYMET Regional Center and its partners produce rainy season regional-level forecasting, yet given the current network of observation stations, the margin of error remains greater than 10 percent in most of their agro-meteorological analyses. The desert and agro-pastoral areas have particularly poor observation coverage. While AGRHYMET has helped localities anticipate and better manage climate risks during the growing season when there is flooding and high stream flows, local analysis remains a critical limitation to improved forecasting. Satellite data can help, but it is sometimes too coarse to be meaningful. While the coastal areas have a stronger network of observations, the factors influencing coastal climate are somewhat harder to predict than the interior drylands. More information is needed on the proximate causes of coastal flooding and drought to develop better coastal hazard forecasting.

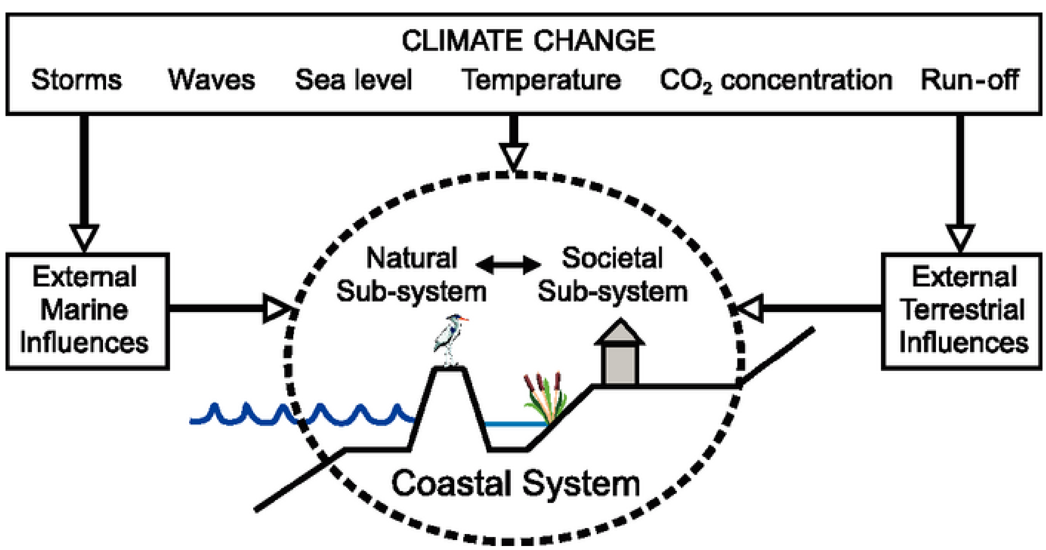
3.0 CLIMATE CHANGE IMPACTS ON WEST AFRICAN COASTAL SYSTEMS

Building on the previous chapter, which briefly describes the state of climate change science in West Africa, this chapter examines the impacts of climate change on coastal biophysical and social systems. It provides: 1) an overview of the range of climate impacts; 2) a description of physical impacts related to erosion and extreme events; and 3) ecosystem impacts on wetlands, nearshore reefs, fisheries, and water and agriculture. Sections 3.2 and 3.3 each include recommendations and opportunities.

3.1 CLIMATE CHANGE DRIVERS IN COASTAL SYSTEMS

The Intergovernmental Panel on Climate Change (IPCC, 2007) puts forward six major climate drivers for coastal systems. These driving forces interact in complex ways with coastal systems, affecting landforms and infrastructure (physical effects), as well as ecosystems (Figure 6). Building on Section 2.0, Table 2 provides a *qualitative assessment* of the level of knowledge and research of the impacts of selected climate drivers on West Africa coastal systems. Based on a rapid review of the peer-reviewed and grey literature (August to September 2013), the assessment starts with the accepted premise that developing countries have been studied less intensely than developed countries. The following subsections explore in more detail the selected physical and ecosystems impacts of changes in these climate change driven-factors.

FIGURE 6. COASTAL CLIMATE DRIVERS



Source: IPCC, 2007

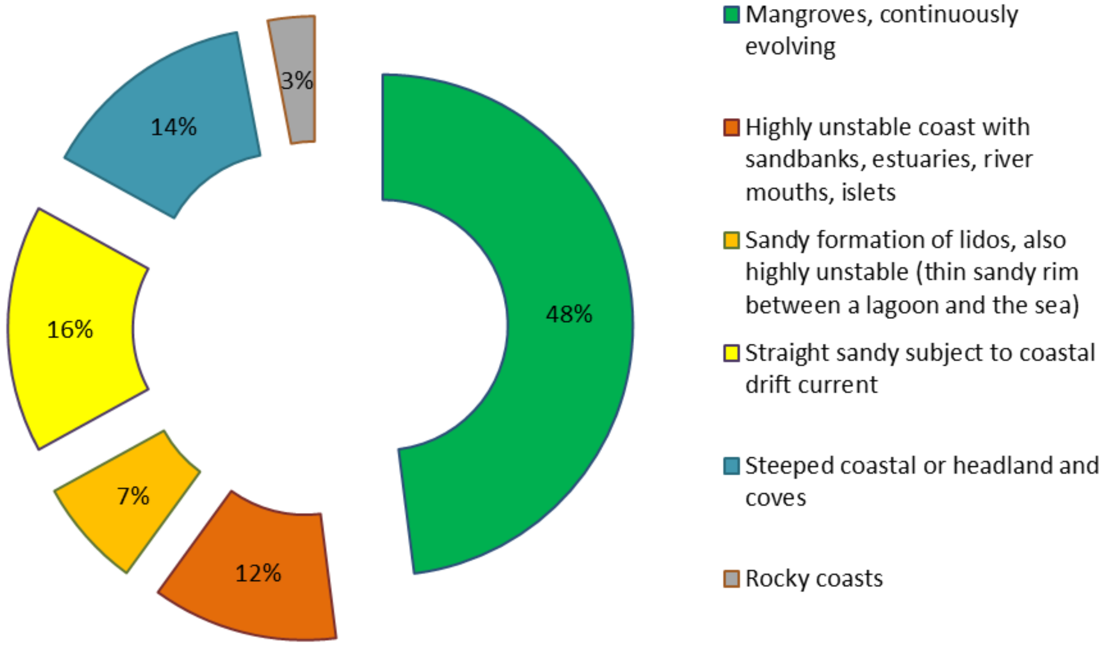
TABLE 2. LEVEL OF KNOWLEDGE OR RESEARCH REGARDING THE IMPACTS OF SELECTED CLIMATE DRIVERS ON WEST AFRICA COASTAL SYSTEMS

Main Climate Drivers in Coastal Systems	Potential Main Physical and Ecosystem Effects of Changes in Drivers on Coastal Systems (based on IPCC 2007)	Level of Knowledge/Research in West Africa Based on Rapid Assessment of Literature	Timeframe/ Certainty & Impact Direction	Source(s)
Ocean Acidification	Absorption of anthropogenic CO_2 and atmospheric deposition of acidity can both contribute to the acidification of the global ocean. Decreased seawater pH can negatively impact pH sensitive organisms. Coral reefs are the most widely recognized ecosystem threatened, as well as commercial fisheries of calcifying organisms (e.g., shellfish).	**Low:** Coral reefs and commercial fisheries of calcifying organisms are not of major commercial importance in the West Africa region; as a result, literature on the topic is limited. However, shellfish fisheries are important for local livelihoods (especially women), and non-calcifying organisms, mainly fish, may also be affected by ocean acidification but this is *new and emerging research.*	Long-term, threshold-based impact, with potentially devastating negative impacts	Bodin et al., 2011, Gosling, 2013
Sea Surface Temperature (SST)	Increased stratification/changed circulation; poleward species migration and changes in species composition; coral bleaching (if any corals are present) increased algal blooms	**Low/Medium:** Some research on historical climate changes (e.g., over 10,000 to 100,000 years) and climate variability exists, including on El Niño/upwelling phenomena and links with rainfall patterns and fish distribution, informing knowledge about future climate change. But understanding of localized impacts of future SST changes is still limited.	Short- to medium-term, differential impacts on species uncertain	Janicot & Fontaine, 1997; Binet et al., 2001; Giresse, 2008; Zeeberg et al., 2008
Sea-Level Rise (SLR)	Inundation, flood, and storm damage; erosion; saltwater intrusion; rising water tables/impeded drainage; wetland loss (and change)	**Medium:** Historic data (50 years) of continuous sea-level rise in West Africa are fairly limited compared with other global regions; deficiency of data has been addressed by the implementation of new tide gauges in recent decades. Studies using sediment core provide information on past climate changes and ecosystems (e.g., over 10,000 to 100,000 years). Future impacts of SLR on coastal zones have been more studied in countries such as Senegal, Ghana, and Nigeria, compared to the rest of the region.	Long-term, and/but contributes to a variety of other impacts	Kim et al., 2010; Niang et al., 2010; Addo et al., 2011; Fashae & Onafeso, 2011; Hinkel et al. 2012
Storm Intensity/ Storm Frequency	Increased extreme water levels and wave heights; increased episodic erosion, storm damage, risk of flooding, and defense failure	**Low:** As for SLR, limited ocean observation network inhibits a better understanding of *future* ocean dynamics. Ocean storm surge events normally occur in the Gulf of Guinea in summer months of April to October with significant impact on infrastructure. Research on the impact of storms, on the impact of storms on shoreline ecosystems, and the compounded effects of SLR and storms on coastal systems is limited, compared to other regions.	Short-/medium-term, predicted increases will be a negative impact	Dasgupta et al. 2009
Wave Action	Altered wave conditions, including swell; altered patterns of erosion and accretion; reorientation of beach form	**Low:** Limited or no information on predicted impacts related to climate change was found, though action is related to wind speed and storm intensity.	Unclear relationship. Increased wave action will have negative impacts.	N/A
Runoff/Changes in Precipitation	Altered flood risk in coastal lowlands; altered water quality/salinity; altered fluvial sediment supply; altered circulation and nutrient supply	**Low/Medium:** Some studies on the impact of changes in runoff on ecosystems have been identified	Short-term with varying, though generally negative, impacts	Niang et al., 2010

3.2 PHYSICAL IMPACTS

The West African coastline is very dynamic, with rocky coasts representing only 3 percent of the coast. The remainder of the coastline is mainly composed of mangroves and sandy formations offering little resistance to the action of the coastal currents (Figure 7) (UEMOA, & IUCN 2010). Changes in climate drivers have the potential to result in significant physical impacts on these unstable and very dynamic coastlines.

FIGURE 7. WEST AFRICA COASTAL ZONE SHORELINE COMPOSITION



Source: UEMOA & IUCN, 2010

3.2.1 Erosion

Coastal erosion impacts the people, environment, and infrastructure along the coastline, and will be exacerbated by sea-level rise, increased storminess, and increased precipitation. Coastal erosion is a complex process (see Box 1), and global warming and sea-level rise will contribute to additional erosion on shorelines, and to the process of stable shorelines beginning to erode (Fashae & Onafeso, 2011). In most cases, climate change is not the main driver of land loss in coastal areas in the short-term; however, in the long-term, sea-level rise may be an important driver.

With climate change, increased erosion of sand systems is expected in West Africa, aggravating the risk of submersion, and resulting in shoreline recession (UEMOA & IUCN, 2010). As described below, beaches and dune ridges along West Africa's coastal area already show evidence of retreat at variable paces: from 1–2 meters to more than 20–30 meters per annum in Senegal and along the Gulf of Guinea, respectively (Niasse et al., 2004). However, it is important to note that, in most cases, loss of land represents both inundation and erosion, and that erosion processes are harder to predict than inundation.

The Senegalese coastal zone, with its sandy coasts and few small lengths of rocky coast, already experiences acute coastal erosion with rates close to 137 meters per year for the area close to the breach in the Sangomar sand spit (Diaw, 1997). Modeling studies in the Cap-Vert peninsula and Saloum Estuary (southern coast of Dakar) estimated under different climate change scenarios land losses due to coastal erosion between 2 and 40 square kilometers by 2080 (Dennis et al., 1995, Niang et al., 2010). However, it is worth nothing that for the study areas, inundation rather than erosion was the cause of higher predicted land loss (1650 to 1746 square kilometers).

From the west of Cote d'Ivoire to Benin, soft sedimentary coastlines are characterized by important lagoon and channel systems experiencing rapid changes. The Ebrié estuary in Côte d'Ivoire is experiencing rapid sedimentation of 6 centimeters per year, while erosion has averaged 8 centimeters per year over the last 50 years (Monde et al., 2001). In Benin, studies using remote sensing and comparing a map of Cotonou dating from 1963 with a picture obtained 24 years later show that the shoreline has retreated by 400 meters at a maximum speed of 16 meters per year, with a total loss of around 1.2 square kilometers of land (Doussou & Glehouneou-Dossou, 2007). The situation in Benin is worrying the population to the point that an organization, *Front uni de lutte contre l'avancée de la mer* (Unified Front against Sea Level Rise, FULAM), was formed representing coastal communities affected by erosion. While studies focusing on hydrological models and agriculture were identified in the literature (e.g., Kouassi et al., e.g., Bormann, 2005), research modeling future changes in coastal erosion rates is scant in Togo, Cote d'Ivoire, and Benin, and the relative role of climate change in this process is unknown.

BOX 1

"Although both coastal inundation and beach erosion hasten shoreline retreat, they are however two distinct processes. Unlike inundation, which drowns land areas, erosion redistributes sediment from the onshore to offshore areas. Sea-level rise does not directly erode beaches and coastal areas. Rather, rising sea levels act as a swelling tide that allows waves to act further up the beach profile and permits larger waves to reach the coast." (Addo et al., 2011)

In Nigeria, the Lagos/Lekki lagoons are part of the barrier lagoon complex, which spans the entire coastline of Lagos State. Erosion occurred along the coastline in 1985 to 2006 with generally higher erosion rates in Ibeju-Lekki, ranging there from 7 to 16 meters over the period, with a total loss of 335 meters of beach line in some area within the period (Obiefuna et al., 2013). Multiple processes take place on coasts, and the compounded effects of increased rates of coastal inundation and erosion can have serious implications for low-lying areas like Lagos/Lekki lagoon in the Niger Delta. In the delta, coastal erosion and inundation estimated from different scenarios of sea-level rise have been shown to accelerate current coastal processes and potentially cause significant land loss (Fashae & Onafeso, 2011). Combined with an observed mean sea-level rise of 0.462 meters above zero level of the tide gauge (data from 1960 to 1970) subsidence ("land sinking") and inundation are already occurring in the Niger Delta (Uyigue & Ogbeibu, 2007). The Niger Delta could lose over 15,000 square kilometers of land by the year 2100, based on an assumption of a one-meter sea-level rise (Uyigue & Ogbeibu, 2007).

Accumulation may occur on coastlines during calm weather, while storm events may result in erosion. Coastal sedimentation and erosion processes are altered by manmade infrastructure, such as the construction of harbor facilities and river dams, further challenging the attribution of impacts to climate change.

In Ghana, sediment supply from the Volta river was affected by the Akosombo Dam, affecting the river's contribution to low-lying areas of coastal plains and accelerating shoreline retreat (Ly, 1980). Construction of harbor facilities also affected the country's coastline: Re-enforcements of waves due to adjacent headlands and manmade structures like breakwaters at the Takoradi Port, Bosumtwi Sam Fishing Harbour, and Naval Base at Sekondi seem to be the most likely cause of erosion in coastal settlements such as Essipon (deGraft-Johnson et al., 2010). Sand and stone extractive activities along the coast have also led to considerable erosion which continues to threaten some communities in the western region. Other human causes arise from improper land use, such as bush burning, overgrazing, and other forms of agricultural land use (deGraft-Johnson et al., 2010). Further south in Cameroon, from Cape Debunscha to Tiko, the coast has undergone severe erosion through harbor installation, shore use, and road building along the shoreline, which interferes with the beach/dune dynamics and has profoundly modified the coastal morphology and the littoral dynamics (Mbuh et al., 2012).

Other problems caused by coastal erosion include salinization of water sources and soil, destruction of ecosystems, and increased coastal flooding. Additionally, when natural coastal habitats such as mangroves are replaced with urban or agricultural uses, the coastline no longer has a natural barrier against wave action and storm surges, resulting in further and increased erosion and flooding. The mining of sand also contributes to erosion by disturbing the surface and exposing the substrate to rain, rivers, and wave action. The construction of oil refineries and wells, gas and oil pipelines, and storage tanks with insufficient setbacks have also been a major cause of erosion for West Africa (UNESCO-IOC, UNOPS, 2006).

A snapshot of erosion concerns for each West African country is provided in Table 3. These concerns are not broken out by the relative importance of climate change as a driver of erosion processes. Various data gaps and the context of each case impede development of a clear understanding of the regional impacts that climate change will have on erosion rates in West Africa coastal countries. As a result, adaptation opportunities should explore resolving the following challenges:

- A major gap in climate data for the region includes sea level and coastal geomorphology information. Additional tidal gauges along the coastline would provide better local sea-level rise trends and provide redundancy for the current gauges in place. Coastal profiles can be created very cost-effectively using basic materials and training local stakeholders or university students. This would provide additional information on coastal erosion rates. Without this data, more detailed, local analysis of risks will be difficult to perform. Such information may be developed in part by assembling historic satellite imagery in comparison with recent imagery.

- Socioeconomic data also is missing for much of the region. Detailed data on coastal assets, including types, values, etc., would allow for a more detailed impact assessment which would help identify localized adaptation strategies. Coastal zone management depends on good data and efforts should be made to collect, develop, and identify multi-country or regional datasets which may be used, such as those acquired through remote sensing. This data could be used to estimate populations, structures, land use/land cover, erosion rates, and soil types.

TABLE 3. EROSION CONCERNS NOT ISOLATING CLIMATE CHANGE IMPACTS

Country	Erosion Concerns of West African Coastal Countries
Cape Verde	It is difficult to determine the current rate of erosion for Cape Verde coastal areas due to a lack of data. However, a recent Adaptation to Climate Change in Coastal Zones of West Africa project report identified that the shoreline along the coast was receding at a rate of more than two meters per year. Coastal erosion may severely impact this 10-island archipelago due to its exposure to the ocean.
Senegal	Senegal has 531 kilometers of coastline, which includes large coastal cities to the south along the "Petite Côte" and north near St. Louis. These areas have erosion rates of one to two meters per year; in addition, an area near the Sangomar offshore bar has recorded erosion rates of up to 137 meters per year. In developed areas, accelerated erosion due to sea-level rise could cost $500 to $700 million (12 to 17 percent of the country's GDP at 1995 values); of this, 20 to 30 percent represents tourist facilities at risk. It is also estimated that 110,000 to 180,000 people (1.4 to 2.3 percent of the 1990 population) could be displaced, the majority of whom are located south of the Cap-Vert Peninsula (Dennis et al., 1995).
The Gambia	Despite the fact that the Gambia has only 50 kilometers of coastline, coastal erosion is still a concern because of the proximity of the capital city of Banjul to the coast. Recession rates of 1.8 meters per year have been recorded for the coastal area between Cape Point and Bald Cape (which includes the area of Banjul). Many tourist areas and structures are under threat and some hotels have had to close.
Guinea Bissau	There are several vulnerable areas along Guinea Bissau's 350 kilometers of coastline. The Varela Beach is subjected to an erosion rate of two meters per year. Other parts of the country that are affected include Bubaque Island and the islands of Porcos and Melo, located in the Bijagos archipelago. Mangroves help reduce coastal erosion in many parts of the coastline.
Guinea	Guinea contains 320 kilometers of coastline fringed with mangrove trees, and the coastal plain supports stands of oil palms. Little data has been compiled on the rate of erosion in this country. Mangroves help reduce coastal erosion in many parts of the coastline.
Sierra Leone	The Sierra Leone coastline extends 460 kilometers and includes 190 kilometers of sheltered coast dominated by extensive mangroves and mud flats. The areas of Konakridee Konakridee, Lumley, Lakka Lakka, and Hamilton are experiencing erosion of four to six meters per year. Some of the beaches on the Freetown Peninsula have other exacerbating factors such as extraction activities for construction purposes, which have contributed to an erosion rate as high as six meters per year.
Liberia	Liberia's 579 kilometers of shoreline run through eight of its 15 counties and house the country's main settlements. Records of erosion rates were destroyed during the civil war, but the government of Liberia estimates that in Buchanan, 250 meters of coastline has disappeared in just under 40 years. Much of this erosion has been caused by unregulated sand mining and looting of metal barriers and rocks used as sea defenses (UNDP, 2012). These materials are mined and looted for use in construction.
Côte D'Ivoire	The Côte d'Ivoire coastline of 1,034 kilometers has an erosion rate of 0.5 to 3.6 meters per year. Most of the industrial, commercial, residential, educational, and military facilities are concentrated in Abidjan, a coastal port city. In 2004, Abidjan appeared on the top of a list of 20 world port cities with the highest population exposure to coastal flooding (Sally Brown et al., 2011).
Ghana	Ghana's 560 kilometers of coastline include its largest cities. In the capital city of Accra, 70 percent of the beach is eroding at a rate of one meter or greater per year. Massive construction projects have created conditions that increase erosion rates in the region. Ada Foah, located in the eastern part of the country, is one of the most vulnerable Ghanian cities, with coastal erosion rates of six meters per year. To help combat this erosion, 67 million Euros were spent to build a seawall along the Ada coastline.
Togo	Togo has a coastline of 56 kilometers and has constructed a breakwater and several jetties near Aneho to protect roughly 15 kilometers of beach. Erosion continues in other places along the coast. Between 1985 and 2000, the Togolese coast receded at an average rate of 10 meters per year in some unprotected areas.

Benin	With its 121 kilometers of coastline, Benin's coastal erosion has been exacerbated following major work undertaken with the construction of the Nangbéto dam, Akosombo dam, and deep-water port of Cotonou, in Ghana; and, in Togo, at the port of Lomé. Houssou Paul, a pilot project funded by the United Nations Environment Program (UNEP) revealed that in 40 years, the coast to the east of Cotonou fell by 400 meters. The Beninese state has decided to prohibit the pumping of sea and sand for the construction of protective dikes.
Nigeria	Nigeria has 853 kilometers of coastline and erosion has already become a major problem, which climate change is exacerbating (Folorunsho and Awosika, 2000). While studies on accelerated marine processes along the coastline are limited despite the socioeconomic importance of the Niger Delta, the available data shows that that coastline erosion has been dominant over accretion of sediment deposition, respectively 59 and 41 percent (Adegoke et al., 2010). Wetlands and mangrove swamps are extensive along the coast of the Niger delta, and can extend 50 kilometers inland and lie up to two meters above present sea level. Projected sea-level rise poses the potential to cause a loss of 17,000 square kilometers of wetlands, in addition to resulting in the inundation and erosion of barrier systems along the western coast of the country (French et al., 1995; Folorunsho and Awosika, 2000).
Cameroon	The 420 kilometers of Cameroon's coastline are composed of barrier beaches, barrier islands, extensive creeks, and lagoons. A high human population on the coastline exacerbates the erosion rates due to urbanization and illegal sand digging. A high percentage of this coastal area's water infiltrates the soil, weathering the pyroclastic material. The Mabeta mangrove and the surrounding coastal creeks experience a high rate of sedimentation, while the area between Man O' War Bay and Mabeta experiences intense weathering. The area between Limbe and Batoke experiences a high rate of erosion caused primarily by wave action. Riverine erosion could provide sediments to stabilize the coastline; however, the riverine sediments often do not reach the sea.

3.2.2 Droughts, Storminess, Floods, and Inundations

Climate change also can create and exacerbate extreme weather events such as droughts, floods, inundations, and coastal storms. Changes in circulation patterns over the last few decades have left the Sahel region of Africa much drier. This period of time represents the most substantial and sustained change in rainfall within the period of instrumental measurements. With lower temperatures occurring south of the equator and higher temperatures north of the equator, rainfall in the Sahel region has decreased. Changes in ocean water temperatures have probably led to a change in atmospheric circulation, which also impacts the amount of rain falling in the Sahel region (Hulme and Kelly, 2012).

West African coastal countries are often impacted by droughts and flooding, including storm surges associated with coastal storms. Depending on which emission scenario projection is used, there may be more or less rain in the region, or the same amount of rain may fall in a shorter time period, producing floods. Inundation could be a significant concern (Awosika et al., 1992; Dennis et al., 1995; French et al., 1995; ICST, 1996; Jallow et al., 1996). As seen in Table 4 below, flooding, drought, and storms have historically been very significant events for the region, and with sea-level rise, storm inundation will be greater. For each country, 10 significant disaster events (in terms of economic loss) are shown. Most events are flood- or drought-related, although a few are related to storms or extreme weather.

The vulnerabilities that underlie the economic loss and loss of life associated with these natural disasters largely continue in all West African countries. Unfortunately, the data on individual events and the locations of disasters (coastal or inland/urban or rural) are not readily accessible.

Adaptation opportunities should initially focus on better understanding country- and site-specific vulnerability to the individual extreme event types identified below.

TABLE 4. OBSERVED IMPACTS OF EXTREME EVENTS IN WEST AFRICA SINCE 1900

Country	Observed Impacts of Extreme Events
Cape Verde	• Drought Statistics: Droughts killed 85,000 (all in the first half of 20th century) and caused an unknown amount of damage. • Storm Statistics: Two storms killed 32, impacted 7,722 people, and caused $3 million in damage.
Senegal	• Flood Statistics: 19 floods killed 72, impacted more than one million people, and caused $54.4 million in damage. • Drought Statistics: Nine droughts impacted 8.4 million people, causing $375 million in damage. • Storm Statistics: Two storms killed 189 people and impacted 96,853.
The Gambia	• Flood Statistics: Eight floods killed 68, impacted 90,169 people, and caused an unknown amount of damage. • Drought Statistics: Eight droughts impacted 1.26 million people and caused $788,000 in damage. • Storm Statistics: Four storms killed five, impacted 16,806 people, and caused an unknown amount of damage.
Guinea Bissau	• Flood Statistics: Four floods killed five, impacted 58,542 people, and caused an unknown amount of damage. • Drought Statistics: Six droughts impacted 132,000 people, and caused an unknown amount of damage. • Storm Statistics: Two storms killed one and impacted 5,425 people.
Guinea	• Flood Statistics: 10 floods killed 19, impacted 365,320 people, and caused an unknown amount of damage. • Drought Statistics: Two droughts killed 12, impacted an unknown number of people, and caused an unknown amount of damage. • Storm Statistics: One storm killed four people, impacted an unknown number of people, and caused an unknown amount of damage.
Sierra Leone	• Flood Statistics: Seven floods killed 166, impacted 221,204 people, and caused an unknown amount of damage. • Storm Statistics: Three storms killed 74, impacted 10,003 people, and caused $3.6 million in damage.
Liberia	• Flood Statistics: Five floods killed 14, impacted 38,410 people, and caused an unknown amount of damage. • Storm Statistics: Two storms impacted 5,500 people.
Côte D'Ivoire	• In 2012, Côte d'Ivoire authorities ordered some 6,000 families living in flood-prone areas in the commercial capital of Abidjan to evacuate; each family was provided $300 to find alternative safe housing. • Disaster statistics have not been collected in the EM-DAT database.
Ghana	• Flood Statistics: 16 floods killed 404 people, impacted 3.86 million people, and caused $108 million in damage. • Drought Statistics: Three droughts impacted 12.5M people, and caused $100,000 in damage.
Togo	• Flood Statistics: 11 floods killed 72, impacted 591,600 people, and causing an unknown amount of damage. • Drought Statistics: Three droughts impacted 550,000 people. • Storm Statistics: One storm impacted 15 people and caused $200,000 in damages.
Benin	• In 2010, flooding caused 56 deaths and 55,000 damaged or destroyed homes. An outbreak of cholera after the event resulted in 846 cases of cholera. • Flood Statistics: 18 floods killed 183 people, impacted 3.15 million people and caused $8.3 million in damage. • Drought Statistics: Two droughts impacted 2.2 million people and caused $651,000 in damage.
Nigeria	• Flood Statistics: 40 floods killed 1,377, impacted 10.2 million people, and caused $621 million in damage. • Drought Statistics: One drought impacted three million people, and caused $71 million in damage. • Storm Statistics: Five storms killed 226 people, impacted 16,012, and caused $1 million in damage.
Cameroon	• Flood Statistics: 12 floods killed 124, impacted 95,000 people, and caused an unknown amount of damage. • Drought Statistics: Four droughts impacted 586,900 people, and caused $1.5 million in damage.

Source: EM-DAT, n.d.

3.3 ECOSYSTEM IMPACTS

In this section, we will explore the impacts of changes in climate drivers on the following coastal ecosystems and ecosystems services:

- Wetlands, including deltas and mangroves;
- Other nearshore environments, including reefs; and
- Fisheries.

3.3.1 Coastal Wetlands

Wetlands can be defined as "areas of marsh, fen, peatland, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, or salt, including areas of marine water the depth of which at low tide does not exceed six meters" (Convention on the Wetlands, 1971, Article 1.1). This encompasses a wide range of aquatic ecosystems covering approximately six percent of the Earth's surface (Rebelo et al., 2010), such as floodplains, swamps and marshes, peatlands, lakes, mangroves, reefs, and river deltas.

In West Africa, while coastal wetlands are mainly composed of mangroves, they are sometimes backed by freshwater swamp forests such as in the Niger Delta; there are also secondary grasslands in the coastal lowlands that flood seasonally, such as in the vicinity of Accra in Ghana (Hughes & Hughes, 1992). Interest in the wetlands of tropical Africa has heightened because of their importance as hot spots for the development and maintenance of biodiversity; their vital role in providing food, water, and livelihood security to the mainly poor people living around them; and, most recently, for their ability to sequester atmospheric carbon (Adekolaa & Mitchella, 2011).

Climate change *could* impact wetlands by changing their hydrologic and ecological environment, for instance through (Erwin, 2009; Hamilton, 2010):

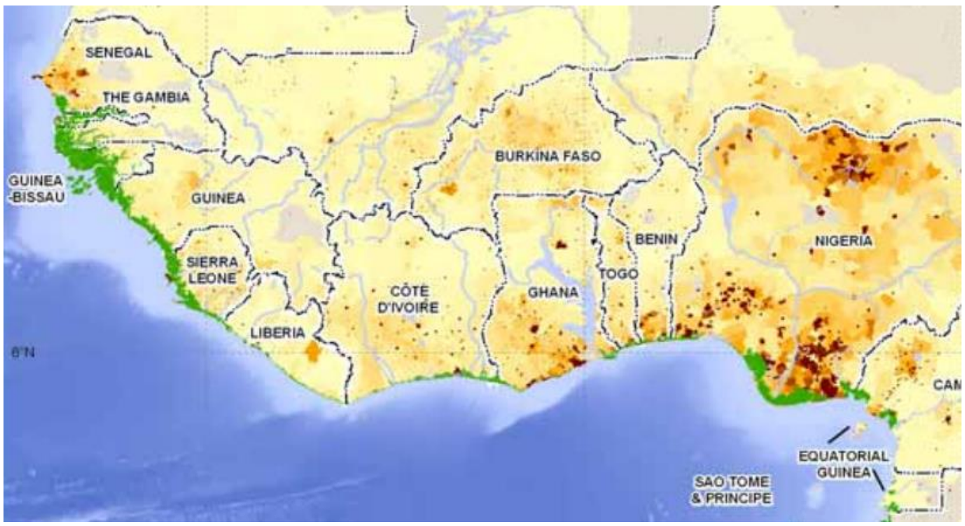
1. Changes in aquatic thermal regimes (water temperature), with implications for thermal optima of plants and animals, rates of microbially mediated biogeochemical transformations, density stratification of water bodies, and dissolved oxygen depletion.
2. Changes in hydrological regimes of discharge and floodplain inundation (water flow), which determine the ecological structure and function of rivers and floodplains, and the extent and seasonality of aquatic environments.
3. Changes in freshwater-seawater gradients where rivers meet oceans, affecting the distribution of marine, brackish, and freshwater environments and the biogeochemical processing of river water reaching the coastal zone. Responses in species' distribution from such changes are not well known, although it is known that many species in coastal wetlands respond to even small changes in water levels.

The state of these hydrological and ecological environments will be concurrently impacted by complex human interactions and feedbacks which are difficult to forecast, and indeed are prone to more uncertainty than climate change impacts. This section will focus on mangroves and deltas, and due to their limited occurrence, reefs will be discussed in the following section.

Mangroves

Mangroves are tropical/subtropical communities of primarily tree species that grow in the intertidal zone. As depicted in Figure 8, the mangrove coastlines from Sine Saloum in Senegal to the Sherbo Islands in Sierra Leone, and in Nigeria, are particularly extensive (UNEP, 2007; UEMOA & IUCN, 2010). The mangrove forests of Nigeria are the largest in Africa and are the third largest in the world, after India and Indonesia (Jalloh et al., 2012).

FIGURE 8. DISTRIBUTION OF MANGROVES IN WEST AFRICA



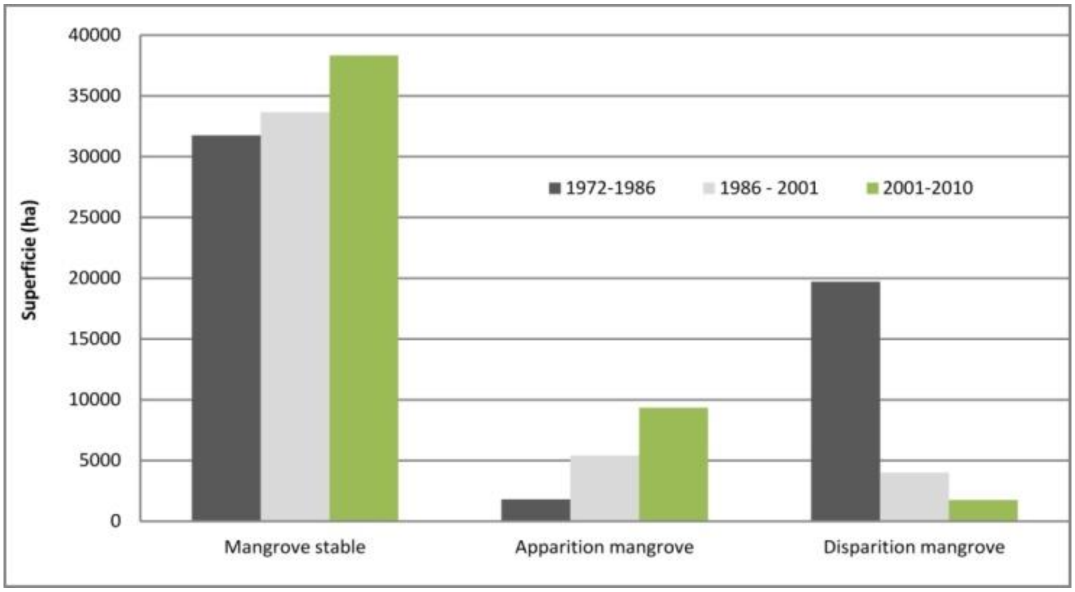
Source: UNEP, 2007

Of the various changes associated with climate, sea-level rise is likely to create the most significant impact on mangroves. Changes in precipitation and temperature may affect the distribution of mangroves, and increased CO_2 levels may increase mangrove productivity, but the responses of mangrove ecosystems to changes in these parameters are not well understood (Gilman et al., 2008).

The Saloum estuary in Senegal is one of the best-studied mangrove systems in West Africa. Niang et al. (2010) determined that the impacts of climate change on the estuary through land losses due to coastal zone inundation (areas being permanently drowned or submerged) have been far more significant than land loss due to coastal erosion. Coastal inundation has the potential to be severe in the Saloum estuary due to its low altitude. A one-meter rise in sea-level could result in inundation of 27 percent of the total land area, 50 percent of which is occupied by mangroves. A two-meter inundation level would inundate 52 percent of the land, which includes almost all the mangroves.

Compounded with changes in sea-level rise, changes in precipitations will also affect mangrove systems in the estuary, as shown by the effect of past climate variability on mangrove composition and distribution. Indeed, during the severe droughts of the 1970s, mangrove areas significantly decreased in the Saloum estuary, but since 1986, regeneration has been observed (Figure 9) (Dieye et al., 2013). The increase in the area of mangrove forest was mainly driven by the wetter conditions between 2001 and 2010 (Conchedda et al., 2011; Dieye et al., 2013). In some areas of the Saloum estuary, movements of species location were observed from *Rhizophora* to *Avicennia,* a species more tolerant of changes in salinity and soil properties (Dieye et al., 2013).

FIGURE 9. MANGROVE REGENERATION IN SALOUM ESTUARY, 1972–2010



Note: ***Apparition*** *represents an increase in mangrove coverage, while* ***disparition*** *represents a loss.*

The well-studied landscape dynamics of the Saloum estuary illustrate the ability of mangrove ecosystems to adapt to changes in rainfall, despite increasing anthropogenic pressures such as deforestation. However, adaptation to inundation due to sea-level rise requires that sediment accretion takes place or lateral shift is made possible for mangrove ecosystems to be maintained in the Saloum estuary (Niang et al., 2010).

Mangroves can adapt to gradual sea-level rise by moving inland through natural dispersal of propagules and maintenance of soil elevation. Indeed, the habitat stability of mangroves depends on the maintenance of soil elevation relative to sea level, which, in the case of sea-level rise, requires surface accretion (Ellison & Zouh, 2012).

To establish the longer term biological history and net sedimentation rate of the Douala-Edea mangrove area in Cameroon, a stratigraphic core was sampled from the seaward edge of mangroves (Ellison & Zouh, 2012). Results showed that this mangrove area located in a low tidal range region has in the past shown resilience and progradation (rate of sediment flux exceeding sea-level rise), owing to sediment supply and accretion, and leading to surface elevation gain. If accretion is at the same rate as relative sea-level rise, then tidal-inundation frequencies are maintained and mangrove vulnerability to rising sea level is much reduced. The analysis of the sediment dynamics of mangrove-colonized tidal flats and bare mudflats in the Sherbro Bay estuarine complex in Sierra Leone also highlighted the important role of accretion in increasing resilience to sea-level rise, by showing how tidal channels export suspended muds in mangrove swamps (Anthony, 2004). Further detailed studies of the interactions between mud dynamics, mangrove substrate behavior, and sea-level rise across a range of sediment supply and sea-level rise rates are needed to better predict mangrove responses (Anthony, 2004).

The indirect impacts of rising sea level will be greatest on mangroves in a West African physiographic setting that provides limited area for landward migration due to the presence of built-up areas and obstacles (UNEP, 2007).

Mangrove elevation and inward migration is a particular challenge in major urban areas such as the Lagos/Lekki lagoon system in the Niger Delta, where built-up areas, due to large-scale conversion of mangroves, limit the ability of the remaining mangroves to adapt to inundation, and increase the risks of flooding (Obiefuna et al., 2013). Peer-reviewed literature on the potential for mangrove elevation and inward migration in other urban centers is limited, such as in Banjul in the Gambia, where, apart from research on fishery-related aspects, studies on the Gambian mangroves remain scarce (Satyanarayana et al., 2012).

Additionally, mangrove elevation and inward migration will also be limited by the type of adjacent ecosystem formation, such as the presence of sand banks or narrow coastal rims, which is the case in the Gambia and Guinea Bissau, where these formations represent a higher proportion of coastline to physiography of mangrove stands compared to Senegal, Guinea, and Sierra Leone (UEMOA & IUCN, 2010).

It is worth stressing that, to date, non-climate-related anthropogenic stressors are the primary threat to mangrove ecosystems worldwide rather than climate change, with losses during the last quarter-century ranging between 35 and 86 percent of global mangroves (Gilman et al., 2008). This loss in mangroves is expected to have a negative impact on the resilience of coastal shores, as mangroves have a tendency to protect shores from coastal hazards such as erosion, flooding, and storm waves and surges (Gilman et al., 2008).

The evidence reviewed on observed impacts of climate variability and future impacts of climate change on mangroves in West Africa suggests that:

- Low-lying sandy coasts (e.g., in Senegal) and mangroves are particularly sensitive to sea-level rise. Inundation due to sea-level rise might be a greater cause of land and vegetation loss than coastal erosion. However, this is based on a limited set of evidence, and more studies like the ones undertaken in the Saloum Estuary are needed; and that
- This gap in knowledge needs to be addressed, as mangrove afforestation (establishment of a forest or stand of trees in an area where there was no forest) and reforestation (reestablishment of forest cover) is seen as a solution to coastal erosion, but its mitigating effects might be limited if planted species cannot withstand higher salinity level; and
- Historically, mangroves have adapted to sea-level rise through processes of progradation (rate of sediment flux exceeding sea-level rise) leading to surface elevation gain and inward migration. However, mangroves surrounded by built-up areas (e.g., urban centers in the Niger Delta) and adjacent to unstable formations or sand banks (e.g., in Gambia and Guinea-Bissau) have a limited capacity for autonomous adaptation.

There is a range of adaptation opportunities associated with mangroves. For example:

- Mangroves may be considered part of an ecosystem-based adaptation strategy to increase resilience to climate change. Ecosystem-based adaptation uses biodiversity and ecosystem services as part of an overall adaptation strategy to help people and communities adapt to the negative effects of climate change at local, national, regional, and global levels. Ecosystem-based adaptation is often considered a win-win strategy, especially in the case of mangroves' role in water regulation and coastal-protection potential in coastal zones. In Vietnam, mangrove restoration and rehabilitation has been promoted for disaster risk mitigation, as a protective function for human lives, and as infrastructures against floods. During tropical cyclone Damrey in 2005, it was suggested that the coastline's restored mangrove system led to a reduction of wave height from four meters to 0.5 meters, and prevented all damage to the sea dike (Powell et al., 2011). As shown by efforts undertaken in Vietnam (Schmitt et al., 2013), reforestation requires a good understanding of historical changes in mangrove cover and future impacts of climate drivers at the local level;

appropriate mangrove-planting techniques to mimic successful natural regeneration; and understanding of coastal processes such as erosion and accretion.

- In West Africa, mangrove protection and rehabilitation initiatives have started and are documented in countries like Senegal, the Gambia, and Cameroun through projects funded by the United Nations Development Program (UNDP), Wetland International, and World Wide Fund for Nature (WWF), among others.[2] Opportunity exists to increase regional knowledge transfer from site-specific experiences to inform future afforestation and (establishment of a forest or stand of trees in an area where there was no forest) reforestation efforts.

Deltas

River deltas are found on the lower reaches of rivers, where the flow of water spreads out and slows down, depositing sediments into expanses of wetlands and shallow water. Deltas, some of the largest sedimentary deposits in the world, are widely recognized as being highly vulnerable to the impacts of climate change, particularly sea-level rise and changes in runoff, as well as being subject to stresses imposed by human modification of catchment and delta-plain land use (IPCC, 2007).

In comparison to wetlands elsewhere, there is a general lack of information on wetlands in Africa, including those of Nigeria's Niger Delta, the third largest wetland in the world and the largest river delta and mangrove ecosystem in Africa, with the greatest extension of freshwater swamps (Adekolaa & Mitchella, 2011).

Climate change presents an added pressure on the Niger Delta, where the wetlands' ecosystems are being eroded through oil and gas exploration, dredging, invasive plant infestation, and wetland reclamation (Adekolaa & Mitchella, 2011).

Sea-level rise and repeated ocean surges will not only worsen the problems of coastal erosion that already exist in the Niger Delta. The associated inundation will increase problems of floods and intrusion of seawater into freshwater sources and ecosystems, destroying such stabilizing systems as mangroves and affecting agriculture, fisheries, and general livelihoods (Uyigue & Ogbeibu, 2007; Asimiea, 2011).

The Niger Delta already frequently experiences flood problems, aggravated by structures such as the Port Harcourt-Patani-Warri highway that cuts across natural drainage lines and acts as a barrier to floodwaters. The blockage of channels by debris and the obstruction of flood paths by new construction were seen as the main obstacles contributing to flooding of Port Harcourt (Douglas et al., 2008). When analyzing long-term historical records of rainfall, runoff, and other climatic factors to investigate hydrological variability and trends in Ghana's Volta River Basin over the period of 1901 to 2002, Oguntunde et al. (2006) showed that the Volta landscape is generally drying only since the last three decades of the 20th century. Both climate and land-use changes may be directly or indirectly linked to the observed trends, with climate likely exacting more influence before 1970 while drastic land-use and cover change (e.g., the building of a dam) has had more effect on runoff since 1970 (Oguntunde et al., 2006).

These examples emphasize the fact that built-up structures and current land-use patterns may exacerbate the impact of climate changes on deltas, and that these anthropogenic activities are likely to have a greater impact on coastal erosion and flooding than climate change during the short term.

---

2 See, for instance, information on conservation initiatives by Wetland International and reforestation initiatives by UNDP and WWF.

Paleontological data, through inferences drawn from pollen analysis, show that in the Tertiary period (from 63 million to two million years ago) the sea level rose and the mangrove swamps grew over large areas while freshwater swamp forests and lowland rainforests became well-established in the Niger Delta (inward development) (Ige, 2011). This again highlights the ability of coastal ecosystems to adapt to a changing climate if accretion and inward migration is possible. However, the natural dynamism of the coastal zone in deltas is often severely constrained by human processes.

Changes in deltas will also affect species biodiversity. While West African mangrove flora has no endemic species and is limited in diversity, a number of African coastal wetlands in deltas are unique habitats for migratory bird species. It is anticipated that the breeding grounds for migratory species will be adversely affected by climate change, but the absence of good-quality monitoring data for many African wetland birds constrains further assessment (Ramsar, 2002). Nevertheless, a recent study by Addo et al. (2011) examined the impact of sea-level rise in the Ghana Dansoman coastal area. The area includes the Densu Delta Ramsar Site, an important habitat for marine and migratory birds, some endangered. Results from modeled projections under the IPCC Special Report on Emissions Scenarios (SRES) SRES A1F1 and SRES B2 scenarios show an increase of sea-level rise between 21.2–79.7 centimeters and 14.0–60.3 centimeters, respectively, by 2100 within this Ramsar site. For the coastal vegetation within the study area, it is projected that a maximum of about six hectares of vegetation would be lost to permanent inundation by the year 2050, and by the year 2100, the coastal area might have lost about eight hectares of vegetation. While this projected land loss could be considered a lower-range estimate compared to other areas such as the Saloum Estuary in Senegal, the potential impacts on biodiversity are significant: the gradual permanent inundation could destroy the entire wetland zone, affecting approximately 35,000 waterfowl (Addo et al., 2011).

These types of indirect impacts on bird biodiversity are likely to be similar in other deltas and estuaries, such as in the Sierra Leone River Estuary, which supports at least eight wintering waterbird species whose numbers in the estuary exceed one percent of their global population, and in the Reserva Natural del Estuario del Muni in Equatorial Guinea, where at least 20,000 waterbirds can often be found during migration (UNEP, 2007).

The evidence reviewed on observed impacts of climate variability and future impacts of climate change on deltas in West Africa suggests that:

- The understanding of the synergistic effects of multiple climate change and other anthropogenic and natural stressors on mangroves is poor, and in West Africa this is compounded by a limited dataset to monitor sea levels along the coast (Woodworth et al., 2007).
- Based on historical climate variability and change, it can be hypothesized that West African deltas in urban areas will be highly vulnerable to climate change, due to the limits to adaptation as a result of the presence of built-up areas.
- In urban and non-urban areas, predicted changes in deltas will also affect species biodiversity, especially Palaearctic migratory birds.

As a result, adaptation-specific efforts are needed related to the following areas:

- More modeling studies on the predicted impacts of climate changes on coastal deltas is needed, similar to those undertaken for inland deltas such as the Okavango Delta in Botswana (Murray-Hudson et al., 2006; Milzow et al., 2010) and the Inner Niger Delta in Mali (Liersch et al., in press).
- However, it is important to understand the limitation of the usefulness of hydrological modeling in data-sparse countries, as highlighted in a recent study in Benin assessing the suitability of different model types for simulating scenarios of future discharge behavior (Cornelissen et al., 2013).

3.3.2 Other Nearshore Environments

The nearshore environment is generally defined as the area encompassing the transition from subtidal marine habitats to associated upland systems. The literature currently available mainly focuses on the impacts of climate change on shoreline changes, erosion, and coastal submersion or inundation. True reefs do not occur along the West African coast or the Cape Verde and Gulf of Guinea archipelagos, although mature coral communities are found at various locations in the Gulf of Guinea, including the hotspot encompassing the four islands (Annobón, Bioco, São Tomé, and Príncipe) off the West African coast.

Reefs

Information on the impacts of climate change on these specific ecosystems is lacking. Nevertheless, a great deal is known about biophysical responses of coral to changes in temperature, light, and salinity. Coral is extremely sensitive to these impacts, and indeed coral bleaching (the widespread death of coral reefs following increased sea surface temperature) has raised one of the most significant global alarms of major impacts of climate change. Significant changes in fish and invertebrate species composition occurs on reefs following bleaching events. Despite their global importance, reefs are unlikely to be a major focus of West African ecosystem vulnerability to climate change, simply due to their limited distribution.

Sandy Systems and Coastal Lagoons

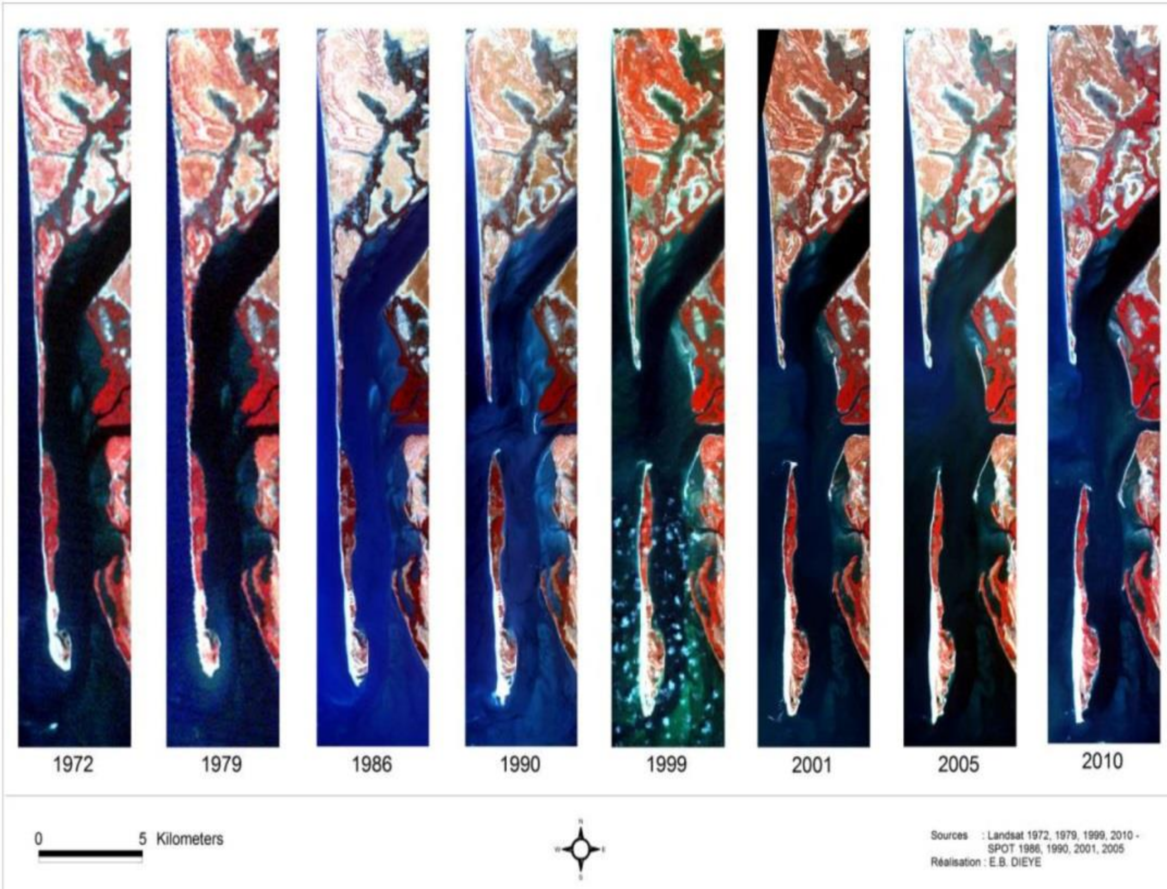
Sandy-beach ecosystems are the world's single largest type of open shoreline (Defeo et al., 2009) and, similar to mangroves, provide a number of ecosystems services to West African coastal communities, such as the provisioning sediment storage and transport; wave dissipation and associated buffering against extreme events; nesting sites for turtles and shorebirds; cultural services through scenic vistas and recreational opportunities; and sustenance of local livelihoods through invertebrate fisheries.

Outside of studies on erosion and sandy systems presented in section 3.2, limited research in West Africa was uncovered on the impacts of climate change on beach ecosystems; this knowledge gap is found in other regions around the world (Defeo et al., 2009). Additionally, in West Africa, several big cities and ports are located on sandy beach plains. These include Grand Bassam and part of Abidjan (Ivory Coast); Lomé (Togo); Cotonou (Benin); and Lagos (Nigeria). As such, climate change impacts of sandy-beach ecosystems will likely be compounded by impacts of human activities along the coast.

Coastal lagoons, associated with sandy-beach ecosystems, are highly productive, supporting livelihoods through intertidal fisheries, as well as providing navigational routes. They differ from estuaries in that they have less freshwater inflow than marine water inflow, and they are naturally ephemeral compared to estuaries: lagoon entrances can become restricted or closed due to storm events pushing sand in from the sea (Chapman, 2012).

In Senegal, changes in the breaking of the “flèche de Sangomar,” a beach shoal in the Saloum estuary (Figure 10) led to increased salinity intrusion, currents, and wave action affecting not only ecosystems but livelihoods with impacts on navigation and intertidal fisheries. The Sangomar experience is an analogue of what could occur with sea-level rise in other nearshore environments dominated by sandy formations. Erosion of beach and lagoon systems can lead to the loss of sea-turtle nesting beaches, as well as the loss of landing sites for fisherfolk, as experienced in the Essipon in the Western region of Ghana (deGraft-Johnson et al., 2010).

FIGURE 10. EVOLUTION OF THE "FLÈCHE DE SANGOMAR" BETWEEN 1972 AND 2010



Source: Dieye et al., 2013

In addition to changes in shorelines, the salinity of lagoons is expected to be altered due to: 1) sea-level rise; 2) the salinization of aquifers; and 3) the possible decrease in freshwater supply (UEMOA & IUCN, 2010). Additionally, some lagoon outlets might be closing or partially closing. The changes could alter species compositions; for instance, change in the composition of seagrass species and invertebrates. Sea-level increase will also reduce light penetration to submerged aquatic vegetation, reducing the photosynthetic potential of these primary producers and changing the nutrient dynamics such that lagoons may be more susceptible to eutrophication (Lloret et al., 2008).

While seagrass meadows provide high-value ecosystem services such as supporting commercial and subsistence fisheries, nutrient cycling, sediment stabilization, and carbon sequestration of carbon, major gaps in information exist for West Africa due to their restricted distribution (Waycott et al., 2009).

The evidence reviewed about observed impacts of climate variability and about future impacts of climate change on nearshore environments in West Africa suggests that a top priority worldwide is to implement long-term field experiments and monitoring programs that quantify the dynamics of key ecological attributes on sandy beaches (Defeo et al., 2009).

3.3.3 Fisheries

Fisheries resources are highly productive along the continental shelf of West Africa. The high productivity is supported by the upwelling resulting from the Canary Current and Guinea Current along the coast (Lam et al., 2012). Fish per capita supply is particularly high in Senegal and Gambia (Table 5). Currently, fish stocks in West African waters are already overexploited, driven to a large extent by the dominance of foreign distant water fleets in the exclusive economic zones (EEZs) of the West African countries, and a strong demand for fisheries resources as a source of food, income, and livelihoods for coastal West African communities (Lam et al., 2012; Pala, 2013; McClanahan et al., in press).

TABLE 5. COUNTRY FISH FOOD SUPPLY

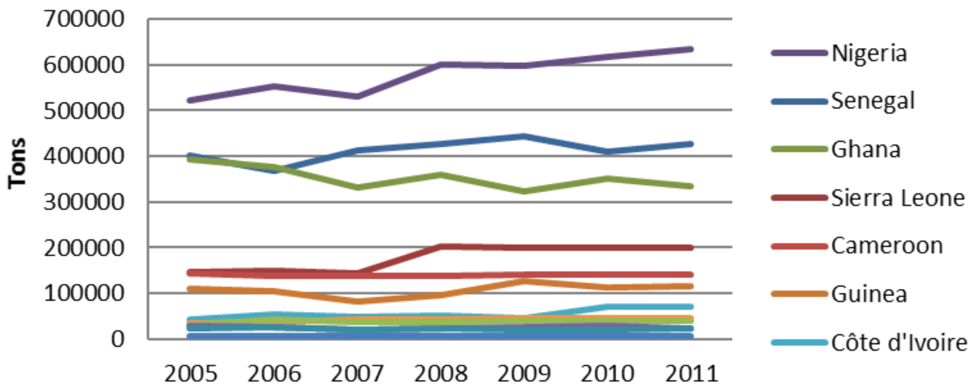
Country	Kg/Capita
Senegal	25.9
Gambia	23.2
Ghana	17.5
Nigeria	14.5
Sierra Leone	14.2
Côte d'Ivoire	12
Cape Verde	9.9
Guinea	7.2
Mauritania	5.7
Togo	4.5
Benin	3.9
Liberia	3.1
Guinea-Bissau	1.2

Note: values are calculated using national populations (United Nations, 2009) and marine capture fisheries data (Lam et al., 2012).

Fisheries resources are considered an important element of food security for West African coastal countries. They are the main source of affordable animal protein, with fish harvested from capture fisheries and aquaculture representing as much as 50 percent of animal protein consumed in these countries (Lam et al., 2012). However, it is worth nothing that sub-Saharan Africa has seen the largest decline (roughly 15 percent) in per-capita consumption of fish between 1990 and 2002, potentially due to an increased exports or catches by foreign fleets; the slow development of aquaculture; fully or over-exploited wild fisheries; and increasing populations (McClanahan et al., in press).

Fish and shellfish are among the primary exports in Cape Verde, the Gambia, Guinea-Bissau, Senegal, and Sierra Leone (Appiah, 2005). In 2011, only three of the 13 coastal West African countries (Nigeria, Senegal, and Ghana) exported more than 300,000 tons of fish and shellfish annually (United Nations, 2013). Figure 11 shows exports for fish captured (does not include aquaculture) over the past seven years for all of the coastal West African countries.

FIGURE 11. FISH CAPTURE TRENDS FOR 12 COASTAL WEST AFRICAN COUNTRIES

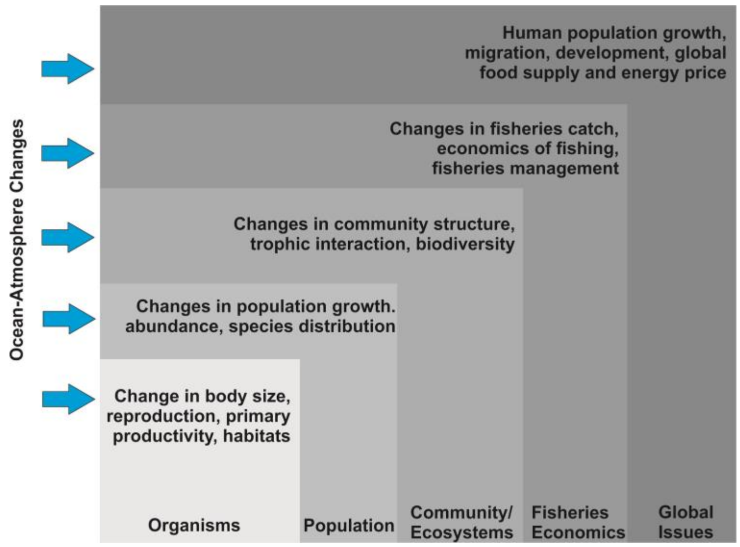


Climate change can affect fisheries through multiple pathways (Figure 12). Changes in water temperature, precipitation, and oceanographic variables (such as wind velocity, upwelling, wave action, and sea-level rise) can bring about significant ecological and biological changes to marine ecosystems and their resident fish populations (Brander, 2009; Cheung et al., 2009; Drinkwater et al., 2009), directly impacting peoples whose livelihoods depend on those ecosystems. Observations, experiments, and simulation models show that climate change will result in changes in primary productivity, shifts in distribution, and changes in the potential yield of exploited marine species (Sumaila et al., 2011). Potential declines in mangrove forest habitat resulting from sea-level rise, changes in sediment, and pollutant loading from river and lake basins could also impact on fisheries by reducing or degrading critical coastal habitats (Badjeck et al., 2010). Mangrove forest loss, for instance, could negatively affect the diversity of benthic invertebrates such as mud crabs.

Extreme weather events may also disrupt fishing operations and land-based infrastructure (Njock & Westlund), while fluctuations of fishery production and other natural resources can have an impact on livelihoods strategies and outcomes of fishing communities (Sarch & Allison, 2000; Coulthard, 2008; Iwasaki et al., 2009).

In this section, predicted changes to West African fishery ecosystems as well as observed changes are discussed.

FIGURE 12. SCHEMATIC DIAGRAM INDICATING THE BIOPHYSICAL AND SOCIOECONOMIC IMPACTS OF CLIMATE CHANGE AT DIFFERENT LEVELS OF ORGANIZATIONS, FROM INDIVIDUAL ORGANISMS TO THE SOCIETY



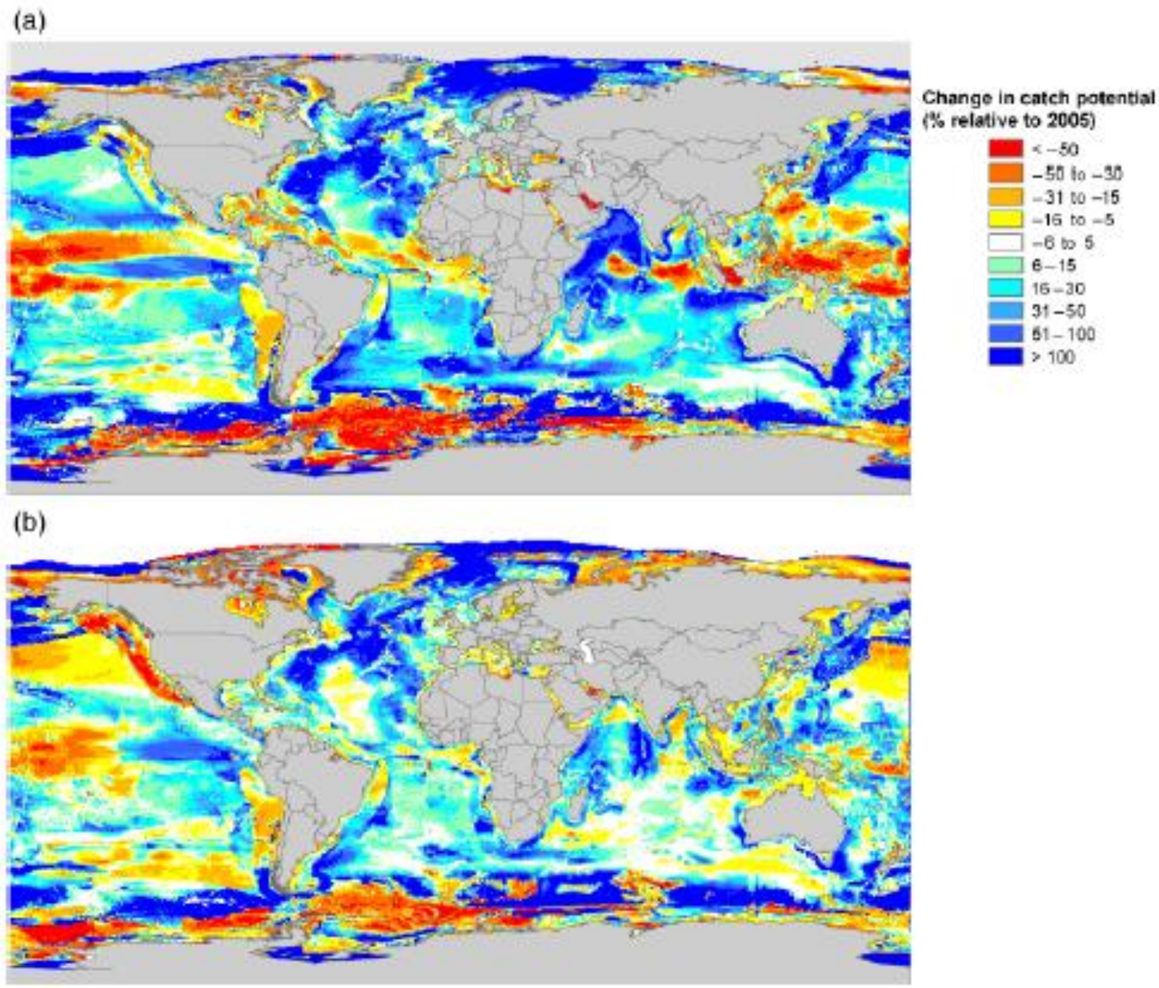
Source: Sumaila et al., 2011

Predicted Climate Change Impacts

Despite the large contribution of marine capture fisheries to global animal protein supply, studies looking at global-scale projections of climate change impacts on marine fisheries are limited. One of these studies by Cheung et al. (2009) projects future changes in maximum catch potential from global oceans by 2055 under various climate change scenarios. Maximum catch potential — a proxy for potential fisheries productivity — is defined as the maximum exploitable catch of a species, assuming that geographic range and selectivity of fisheries remain unchanged from 2005, the most recent year for which data is available.

The study shows that climate change may lead to large-scale redistribution of global catch potential, with an average of 30 to 70 percent increase in high-latitude regions and a drop of up to 40 percent in the tropics (Figure 13). In the Atlantic Ocean, the projected magnitudes of change in the tropical and temperate regions is smaller than those in the global average and the Pacific Ocean, but still relatively high in West Africa (between 5- and 50-percent changes from the 2005 level) (Cheung et al., 2009). While the study provides an important basis to understand climate change impacts on marine capture fisheries, it is important to note that various uncertainties are associated with the projections, such as changes in ecophysiology (for example, the increased physiological stress resulting from ocean acidification) (Cheung et al., 2009).

FIGURE 13. CHANGE IN MAXIMUM CATCH POTENTIAL (10-YEAR AVERAGE) FROM 2005 TO 2055 IN EACH 300X300 CELL UNDER CLIMATE CHANGE SCENARIOS: (A) SPECIAL REPORT ON EMISSION SCENARIOS A1B, AND (B) STABILIZATION AT 2000 LEVEL



Source: Cheung et al., 2009

A similar study by Lam et al. (2012) focused just on the western African region, calculating the potential change in maximum catch potential by the 2050s (i.e., average of 2050 to 2059) relative to the 2000s (i.e., average of 2001 to 2010) in 14 coastal countries' EEZs. Under a high-range greenhouse gases emission scenario (SRES A1B), the potential loss in total annual landings from these countries by the 2050s is estimated to be 26 percent over current levels.

The EEZs of six countries (Ghana, Côte d'Ivoire, Liberia, Togo, Nigeria, and Sierra Leone) are projected to suffer substantial reductions in landings, of up to and more than 50 percent of their current production under the SRES A1B scenario (Table 6). These countries with large reductions in landings are located near the equator.

TABLE 6. CURRENT LANDINGS, PROJECTED LANDINGS, PERCENTAGE CHANGE IN LANDINGS OVER CURRENT LEVEL AND THE PREVALENCE OF UNDERNOURISHMENT IN THE POPULATION OF EACH WEST AFRICAN COUNTRY UNDER TWO DIFFERENT CLIMATE CHANGE SCENARIOS

EEZ Country	Current landings in the 2000s (t)[a]	Low-range GHG emission scenario (constant 2000)		High-range GHG emission scenario (SRES A1B)		Prevalence of undernourishment in total population (2000–2002) (%)
		Projected landings in the 2050s (t)[b]	Potential percentage change in catch over current level (2000s)	Projected landings in the 2050s (t)[b]	Potential percentage change in catch over current level (2000s)	
Ghana	264 796	154 806	−41.5	119 243	−55.0	12
Côte d'Ivoire	58 268	35 752	−38.6	25 434	−56.4	15
Liberia	22 848	14 599	−36.1	11 318	−50.5	43
Togo	14 907	10 520	−29.4	5 959	−60.0	41
Nigeria	288 140	220 682	−23.4	136 456	−52.6	10
Sierra Leone	59 307	51 000	−14.0	27 723	−53.3	51
Guinea	107 380	97 331	−9.4	79 924	−25.6	18
Benin	8 148	7 456	−8.5	6 172	−24.2	22
Cape Verde	17 007	15 996	−5.9	13 328	−21.6	19
Guinea-Bissau	13 351	12 940	−3.1	10 331	−22.6	29
Gambia	32 147	34 471	7.2	29 637	−7.8	29
Western Sahara	821 642	890 892	8.4	691 230	−15.9	–
Mauritania	293 861	327 211	11.3	251 541	−14.4	7
Senegal	608 982	717 029	17.7	527 598	−13.4	32
West Africa region (14 countries)	2 610 786	2 590 686	−8	1 935 895	−25.9	15

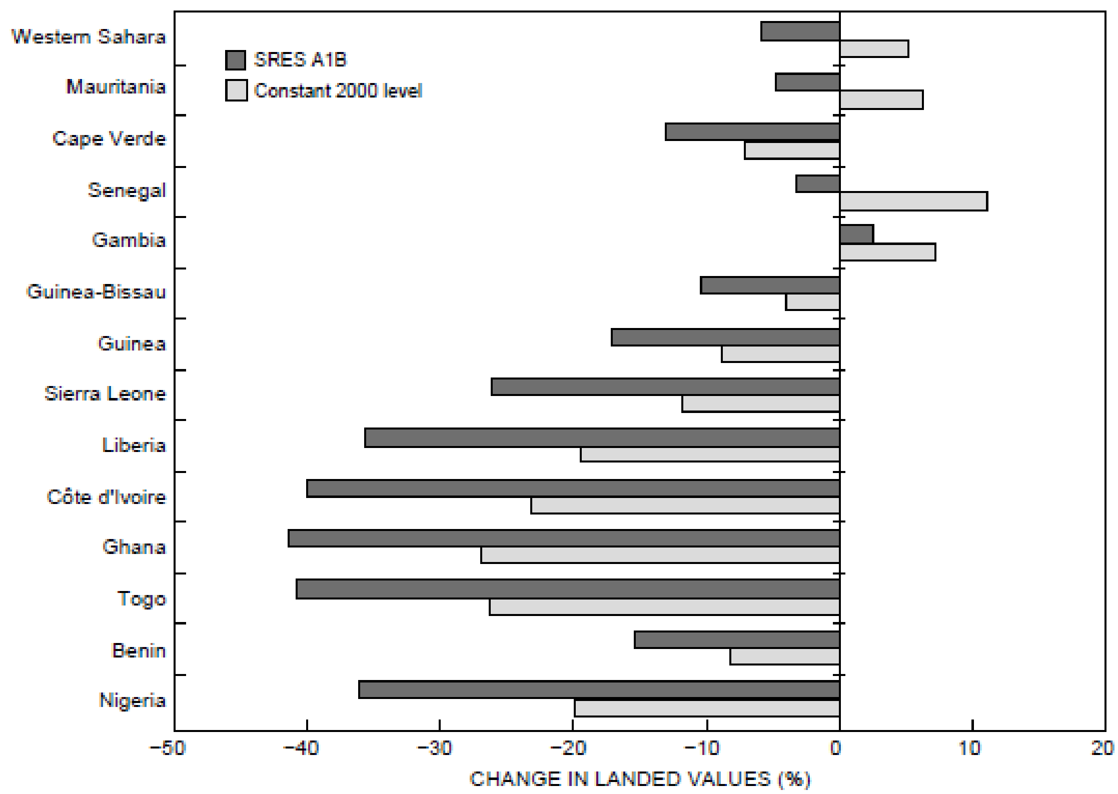
[a] Average annual landing data from 1999 to 2003 obtained from the Sea Around Us Project catch database (www.seaaroundus.org)
[b] Annual landings in the 2050s projected by using the model described in the text

Note: GHG = greenhouse gas. Source: Lam et al., 2012

These reductions in landing can have significant socioeconomic implications. In Senegal, 47 percent of animal protein intake comes from fisheries (FAO, 2005) and the sector generates 600,000 direct and indirect employment opportunities (*Minist ère de l'Economie maritime des Transports maritimes, de la Pêche et de la Pisciculture,* 2007). In Mauritania, the sector is export-oriented, contributing to foreign exchange earnings and the budget envelope: 20 percent of the government budget came from the sector between 1993 and 2000 (MAED, 2002). Additionally, countries such as Sierra Leone, Liberia, and Togo have already had high proportions of their populations in a condition of undernourishment (greater than 40 percent), so reductions in their landings would have great implications in terms of food security (Lam et al., 2012).

Lam et al. (2012) projected that these changes in landings can result in a 21-percent drop in the landed value, a 50-percent decline in fisheries jobs, and a total annual loss of $311 million by 2050 for the region. Almost all of the countries under study show reductions in their landed values from fish caught in their EEZs except Gambia (Figure 14). Côte d'Ivoire, Ghana, and Togo will suffer the greatest impact on their landed values, with up to 40-percent declines under the SRES A1B scenario by the 2050s.

FIGURE 14. PERCENTAGE CHANGE IN LANDED VALUE OF FISHING COUNTRIES IN WEST AFRICA FROM 2000 TO 2050 UNDER HIGH-RANGE CLIMATE CHANGE SCENARIO (SRES A1B) AND LOW-RANGE CLIMATE CHANGE SCENARIO (CONSTANT 2000 LEVEL)



Source: Lam et al., 2012

Observed Climate Variability Impacts

Important environmental variability occurs on seasonal, inter-annual, and decadal scales in the Guinea Current Large Marine Ecosystem, part of the Central West African Upwelling system. Seasonal variability is dominated by upwelling,[3] which has two peaks: December to February (the "minor" season) and July to September (the "major" season) (Perry & Sumaila, 2006). The upwelling results in exceptionally high primary and secondary productivity which sustains a large variety of pelagic species, including commercial fish species like *Sardinella* (Zeeberg et al., 2008). Inter-annual variability is related to the basin scale variability of the tropical Atlantic and to large scale atmospheric changes induced by El Niño-Southern Oscillation events in the tropical Pacific Ocean (Perry & Sumaila, 2006). Changes in flood regimes can also affect fish productivity through changes in salinity levels (Binet et al., 2001).

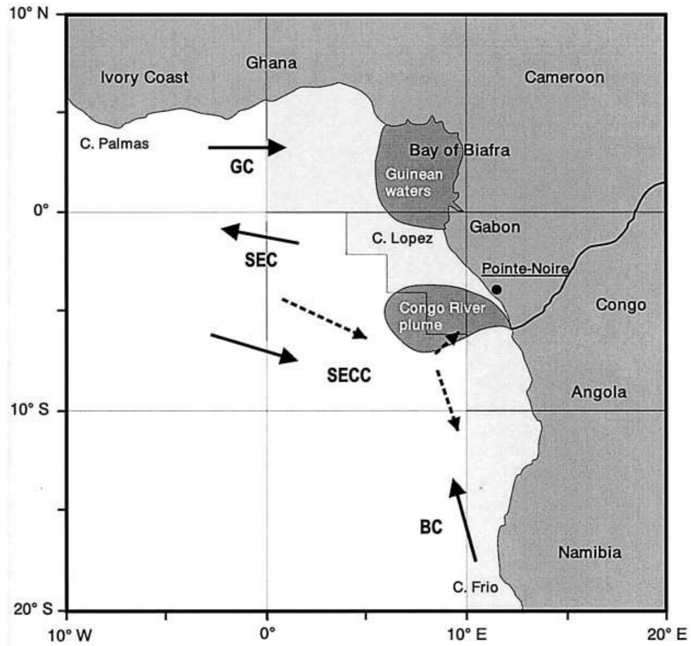
Binet et al. (2001) have shown that changes in fluvial regimes of the Congo River and the two types of Atlantic Niños affected the abundance of *Sardinella* species. In the Congo's fisheries, decadal variations of

---

[3] Upwelling is an oceanographic phenomenon that involves wind-driven motion of dense, cooler, and usually nutrient-rich water towards the ocean surface, replacing the warmer, usually nutrient-depleted surface water. Increased nutrients lead to high primary productive (e.g., phytoplankton), leading to high secondary productivity (e.g., fish production).

catches of two species are consistent with regime shifts of the Congo River: *Sardinella maderensis* is dominant when the outflow is above average (1960s and 1970s) and is replaced by *Sardinella aurita* when the runoff is weak (1980s and 1990s). The Guinea and Benguela Niños seem to boost *Sardinella aurita* fishing in Ghana, the Ivory Coast, and the Congo. In southern Angolan waters, *Sardinella* species are driven southward, towards Namibia, by the warm water influx (Figure 15).

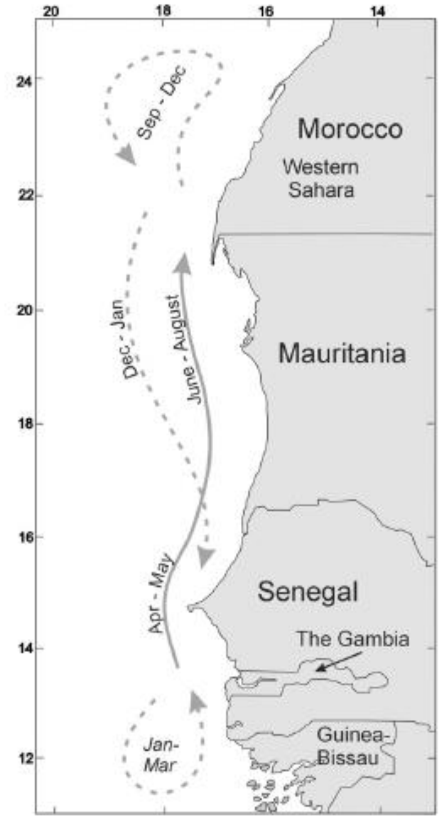
FIGURE 15. MAP OF THE GULF OF GUINEA AND SOUTHEAST ATLANTIC OCEAN



Map indicates the three areas (light shadow) from which the sea surface temperatures are averaged: Guinea (0°–6°N, 0°–10°E), Gabon–Angola (0°–10°S), and Benguela (10°–20°S). Dark shadowed areas: freshwater pools of Guinean water and the Congo River plume. GC: Guinea current; SEC: south equatorial current; SECC: south equatorial counter current in normal years (full line) and during warm events (broken line); BC: Benguela current. Source: Binet et al., 2001

A similar change in species' geographical distribution induced by climate variability has also been observed in the northern part of West Africa, between Guinea-Bissau and Mauritania (Canary Large Marine Ecosystem). Zeeberg et al. (2008) showed that a shift into warmer sea surface temperatures in 1995 appears to have shifted the optimal habitat for feeding and spawning for round *Sardinella* from Guinea-Bissau and Senegal northwards towards Mauritania for longer period, altering the annual migration pattern (Figure 16). These observed changes induced by inter-annual climate variability highlight the potential transboundary management challenges that climate change could bring to fisheries management in West Africa, and the potential overfishing during warm events.

FIGURE 16. MIGRATION PATTERN OF SARDINELLA AURITA IN WEST AFRICA, REFLECTING THE CHARACTERISTICS OF REGIONAL OCEANOGRAPHY AND SEASONALITY



Source: Zeeberg et al., 2008

The evidence reviewed about observed impacts of climate variability and about future impacts of climate change overall suggests that:

- The EEZs of six countries — Ghana, Côte d'Ivoire, Liberia, Togo, Nigeria, and Sierra Leone — are projected to suffer substantial reductions in landings;
- Côte d'Ivoire, Ghana, and Togo will suffer the greatest impact on their landed values, with up to 40-percent declines by the 2050s;
- These projections are associated with various uncertainties, such the potential increased physiological stress resulting from ocean acidification; and
- These observed changes induced by inter-annual climate variability highlight the potential transboundary management challenges under a changing climate.

Localized changes in the productivity of marine and inland waters induced by climate change will pose new challenges to the fishery and the aquaculture sectors in West Africa. Faced with declining yields, income, and food security, fishers may seek alternative livelihoods, placing pressures on other sectors or resources. For example, when coastal fisheries' resources are scarce, fisherfolk adopt alternative livelihood strategies, including hunting for bushmeat (Brashares et al., 2004). It is worth nothing that climate change does not occur in isolation of other drivers of change: Processes of environmental, economic, and social change can affect the fishery sector, potentially creating additional vulnerability to climate change.

There are a range of adaptation measures to respond to climate change stresses to coastal fisheries. These may include the following:

- A major area for identifying and implementing adaptation measures may involve improving the techniques and equipment used by artisan fisherman. According to Jamal Saghir, World Bank director of sustainable development for the Africa Region, the fisheries across Africa support some 10 million livelihoods, and “With better governance, these fisheries could generate at least an additional $2 billion each year. Unlike minerals and other nonrenewable resources, this would be a continual contribution to food security, poverty reduction, and economic growth throughout the region.”
- Another potential area for implementation of adaptations to climate change involves increases in the amount of fish and shellfish that can be harvested through aquaculture (United Nations, 2013). Since most of the West African countries do not engage in significant levels of production from aquiculture, this activity may represent a good opportunity for increasing each country’s production levels of fish and shellfish. However, the development of additional aquaculture capacity must be carefully planned to avoid possible vulnerability from climate change and to avoid significant environmental problems that may result from aquaculture activities.

4.0 LIVELIHOODS/HUMAN IMPACTS

The following sections describe the assets that reside in the rural and urban areas within the coastal zones of Cape Verde, Senegal, the Gambia, Guinea-Bissau, Guinea, Sierra Leone, Liberia, Cote d'Ivoire, Ghana, Togo, Benin, Nigeria, and Cameroon. These sections also describe examples of the predictions about the losses that may be suffered within each of these assets in the event that the potential impacts of climate changes are not addressed by technical and social adaptation techniques.

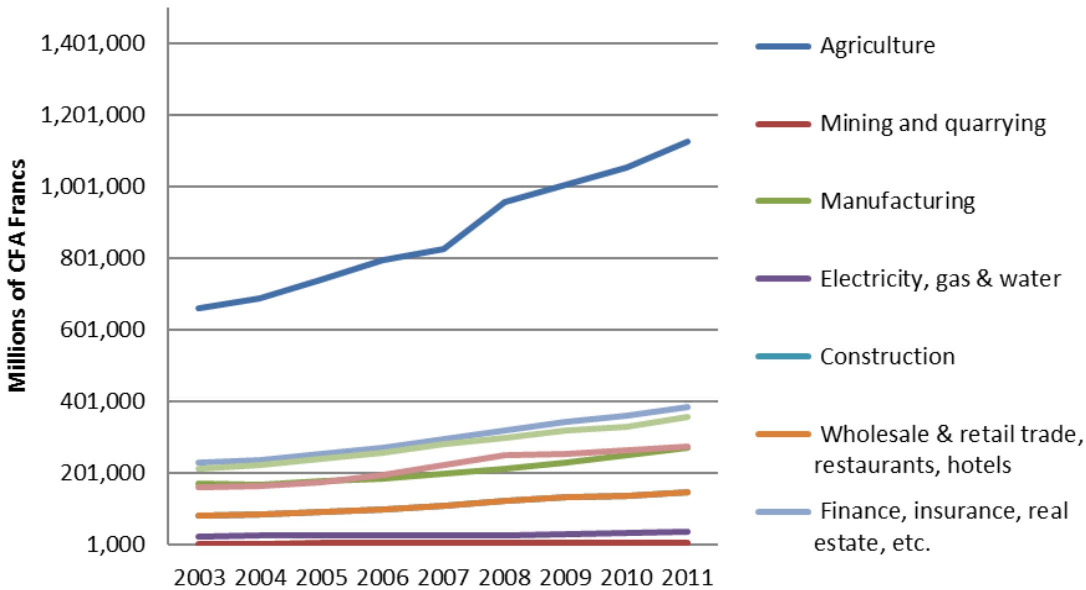
4.1 CROPS

Growing populations, inappropriate agricultural practices, and changing climate in the region are influencing the composition and ability of agroecosystems in providing much-needed ecosystem services (Jalloh et al., 2012). While the impact of climate change on West African agriculture is an active area of research, the majority of this work focuses on the Sahel region or localized studies. The variety of coastal cash crops across West African countries, ranging from coffee to cocoa to oil palm to rubber, will have varying responses to climate impacts.

The agricultural outputs of the West African coastal countries comprise an average of roughly 30 percent of their respective economies and employ up to 80 percent of their respective populations. Figure 17 illustrates how important agricultural outputs are to the coastal countries of West Africa economies by comparing the value of Benin's agriculture exports to the values of its exports from other economic sectors. The relationship between agriculture and other industries in Figure 17 is similar across West African countries, and also demonstrates that Benin's agricultural exports are steadily rising and that this country has numerous other products that support its economy. However, it should be noted that the numbers shown in Figure 17 actually understate the importance of agriculture in Benin because these numbers are only export values, which do not include the value these crops provide in feeding the majority of Benin's rural population, which is mostly comprised of small rural farming families. Figure 18 shows the agricultural yields in Benin over the past seven years. This figure demonstrates that Benin's agricultural yields are increasing and that Benin's agricultural crops are not dependent on the success of only one or two crops. However, this figure shows that the two crops responsible for the highest production (cassava and yams) are typically grown in tropical humid climates, which are in the southern portions of the country nearer to the coastline.

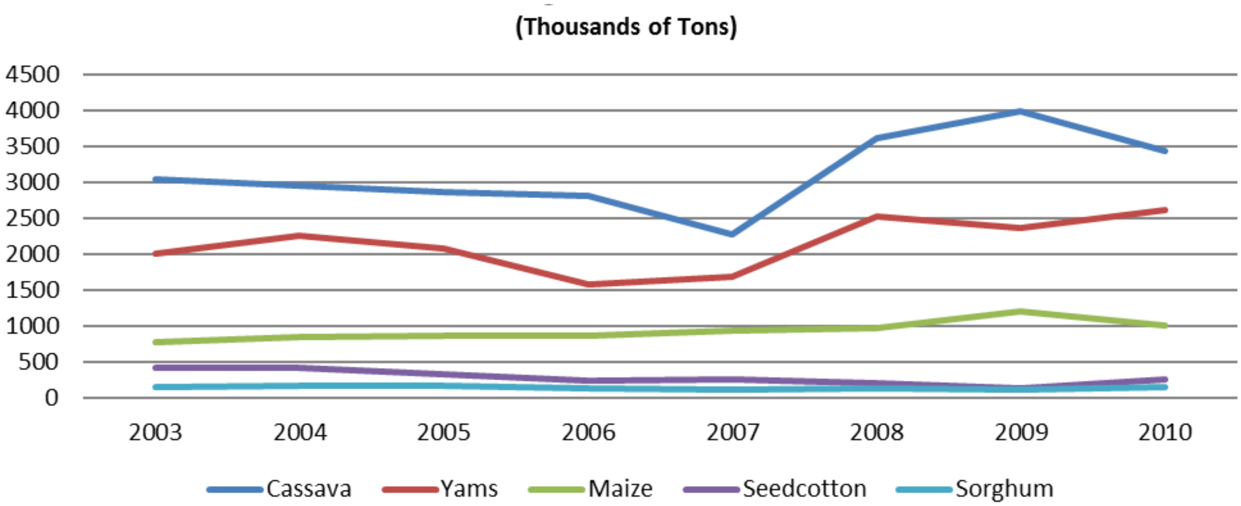
The International Food Policy Research Institute (IFPRI) has released a regional overview of climate change impacts on agricultural crops on a country-by-country basis. This analysis focuses primarily on subsistence crops, not on the coastal cash crops of coffee, cocoa, rubber, and oil palm. The analysis presents yield change estimates across crops for 2000 to 2050 under different climate and technological change assumptions. In most cases, increased inputs and use of improved techniques are expected to mediate climate change impacts; however, the yield of most crops are expected to decline along the coast due to a modeled reduction in rain along the coast within the IFPRI models (IFPRI, 2013). It identifies at a coarse scale some regions within countries that may be more suitable given a changing climate, including pockets for improvement of rice-growing conditions. The International Center for Tropical Agriculture estimates that rising temperatures could impact the ability of cocoa plants to access enough water during the growing season in Côte d'Ivoire and Ghana, resulting in the need to move cocoa production with changing temperature regimes, or begin planting new adapted cocoa varieties.

FIGURE 17. VALUES OF EXPORTS FROM BENIN



Source: African Development Bank Group, the African Union Commission, and the United Nations Economic Commission for Africa, 2012

FIGURE 18. AGRICULTURAL YIELDS FROM BENIN



Source: African Development Bank Group, the African Union Commission, and the United Nations Economic Commission for Africa, 2012

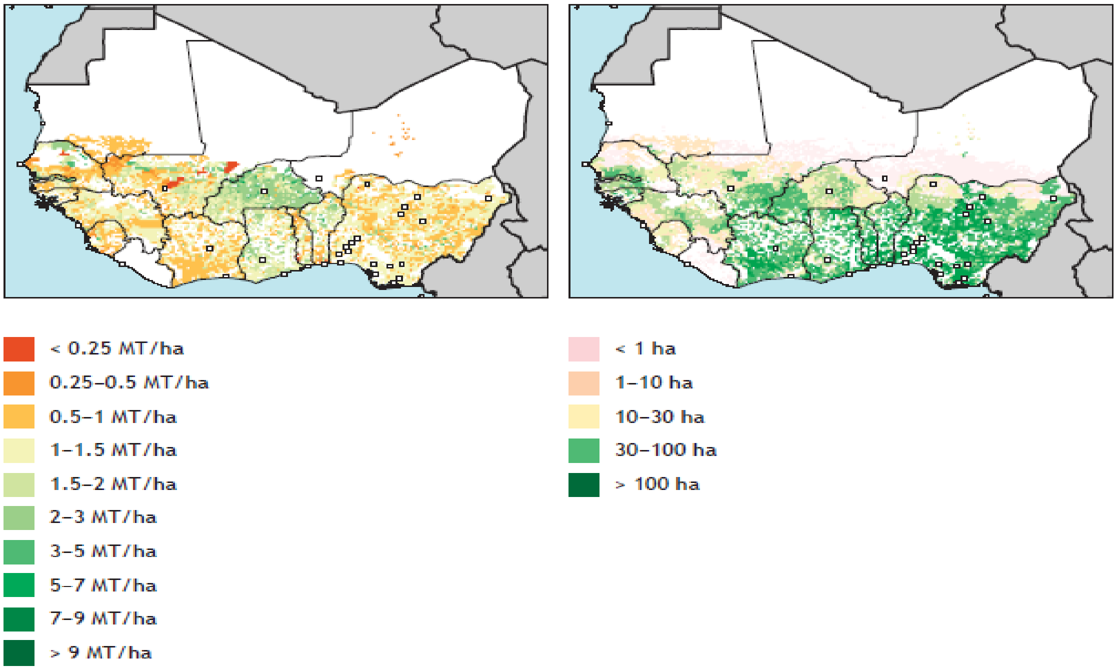
Despite these potential coastal impacts, at a national scale, models of agricultural production in coastal West African countries appear to suggest future growth of production. For example, Table 7 presents modeling results for the production rates for maize, which represents one of the major agricultural crops grown in the West African coastal areas (IFPRI, 2013; FAO, 2010). The predicted production rates shown in this table indicate that production of maize is expected to increase at the national level, despite the potential effects of climate change on the coasts. This highlights the importance of understanding crop projections within countries and not just national-level studies.

TABLE 7. CHANGES IN MAIZE PRODUCTION IN WEST AFRICA UNDER THE BASELINE SCENARIO, 2010 AND 2050

Country	Maize Production (metric tons)		
		2050	
	2010	Min	Max
Benin	810	1,660	1,911
Burkina Faso	646	900	1,105
Côte d'Ivoire	824	1,601	1,661
Gambia	31	43	48
Ghana	1,255	2,311	2,538
Guinea	159	344	386
Guinea-Bissau	31	37	41
Mali	531	703	803
Niger	3	2	3
Nigeria	6,070	7,664	9,181
Senegal	263	398	439
Sierra Leone	20	30	33
Togo	531	567	661

Source: Based on analysis conducted for Nelson et al. (2010). Notes: The minimum (min) and maximum (max) price increases arise from the differences in the climate model effects on yields

FIGURE 19. YIELD (METRIC TONS PER HECTARE) AND HARVEST-AREA DENSITY (HECTARES) FOR RAIN-FED MAIZE IN WEST AFRICA, 2000

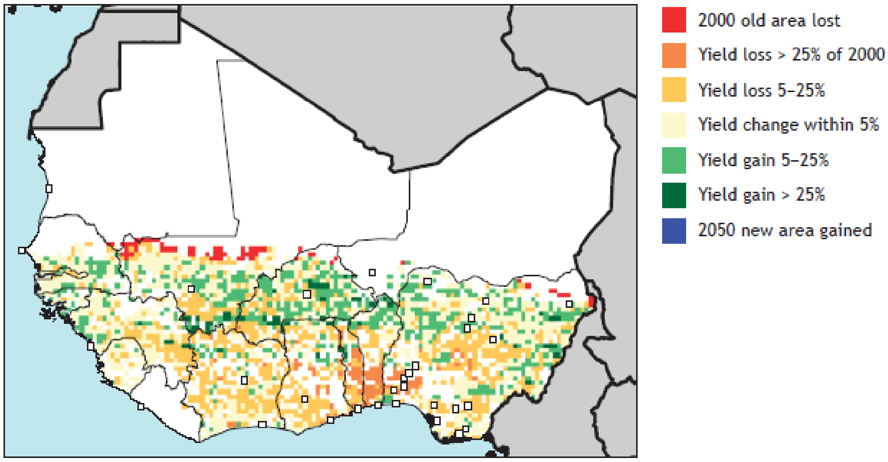


Sources: SPAM (Spatial Production Allocation Model) (You and Wood, 2006; You, Wood, and Wood-Sichra 2006, 2009). Notes: ha=hectare; MT/ha=metric tons per hectare.

Figure 19 shows the projected impacts that may occur to maize crops in the West African countries as a result of climate changes predicted by two models (shown in Figure 20). These two figures show that reductions in percent yields of maize crops on the order of five to 25 percent are expected to occur close to the coastal areas of most countries due to climate changes. However, Senegal and Guinea are expected to have gains of five to 25 percent in some coastal areas. These figures also illustrate gains in maize production in the noncoastal areas that are nearer to the Sahel.

FIGURE 20. PROJECTED CHANGE IN MAIZE YIELDS BETWEEN 2000 AND 2050 UNDER A RANGE OF CLIMATE SCENARIOS

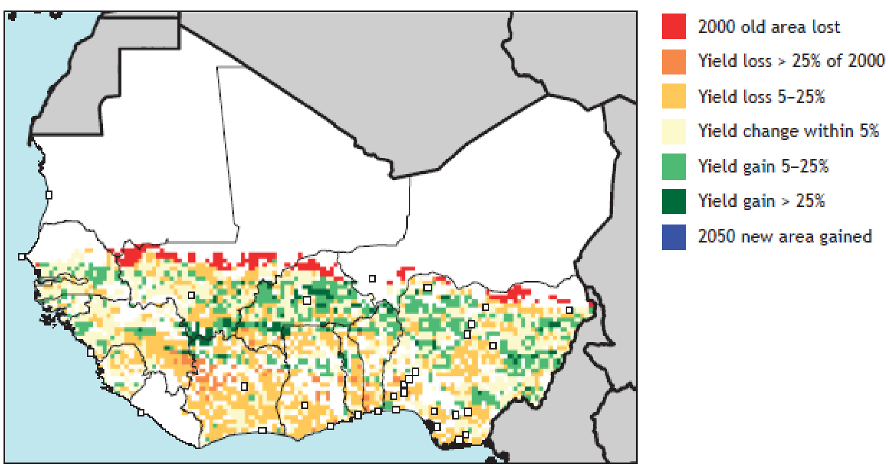
Changes in yields (percent), 2000–2050, from the DSSAT crop model, maize (rainfed), CSIRO A1B



Source: Authors' estimates.

Notes: A1B = greenhouse gas emissions scenario that assumes fast economic growth, a population that peaks midcentury, and the development of new and efficient technologies, along with a balanced use of energy source; CSIRO = climate model developed at the Australia Commonwealth Scientific and Industrial Research Organisation; DSSAT = Decision Support Software for Agrotechnology Transfer.

Changes in yields (percent), 2000–2050, from the DSSAT crop model, maize (rainfed), MIROC A1B



Source: Authors' estimates.

Notes: A1B = greenhouse gas emissions scenario that assumes fast economic growth, a population that peaks midcentury, and the development of new and efficient technologies, along with a balanced use of energy sources; MIROC = Model for Interdisciplinary Research on Climate, developed at the University of Tokyo Center for Climate System Research.

Source: IFPRI, 2013

Coastal rice is of particular interest due to its intensive use of water. About 150,000 hectares, representing four percent of the rice area in West and Central Africa, are planted to mangrove swamp rice in Sierra Leone, the Gambia, Guinea, and Guinea-Bissau. Mangrove swamps have appreciable native soil fertility that makes the mangrove ecology attractive to low-input rice farmers; they are mainly cultivated in the saline water flood plains. These farmers largely depend on natural processes involving accumulation of leaf litter and subsequent decomposition for the maintenance of soil fertility (Jalloh et al., 2012). Changes in salinity, sea-level rise and extreme events could affect these ecosystems as well as lead to losses of crustaceans and oysters, which have limited mobility compared to fish.

In their study on the impact of climate change on estuaries in Senegal and Cape Verde, Niang et al (2010) showed that the combination of sea-level rise and decreased precipitation will increase the saltwater intrusion in a number of coastal aquifers, especially around Dakar and in the Saloum estuary. This will pose risks to water supply in a context of growing demand especially in the capital city of Dakar and agriculture. Currently in Senegal, the tannes (highly saline soil, non-arable land) are advancing landward, these “white lands” reducing the arable land available to nearby populations (Thiobane, no date).

It appears that continued improvements can be predicted in the near term for the economies and livelihoods for the coastal West African countries. Despite recent improvements in agricultural production, this does not appear to be directly linked to an improvement in livelihoods. For resilient agricultural systems to develop, there is a need for the following:

- More research on the smallholders will provide more information on potential strategies for increasing crop yields to levels in which the smallholders have more of a chance to earn enough money to escape poverty. The techniques used by many of these smallholders may be useful to the larger operations that are increasing their wealth by selling their products. Alternatively, more research into the techniques of smallholders may help to identify how to teach them new techniques borrowed from larger farms for increasing their yields and diversifying their crops. Summarizing climate change impacts on agriculture in the West African countries, Rocio Hiraldo notes that, “Given the small scale in which most West African agriculture develops, small-scale farmers should be the focus of future climate change actions. Providing them with support to achieve water and soil management will be key strategies to increase their resilience to adverse climatic conditions and hence reduce poverty in a changing climate” (Hiraldo, 2011).
- Another need for more research is illustrated by the many conflicting predictions of crop yields provided by individual climate change models and individual countries. For example, the *USAID Background Paper for the ARCC West Africa Regional Climate Change Vulnerability Assessment* (USAID, 2013) stated: “A survey of findings from 16 statistical and process-based models analyzing West African crops by Roudier et al. (2011) … shows a wide variation of results, ranging from a decrease in yield of -50 percent to an increase in yield of +90 percent.” It is also advisable to test a wider range of model projections prior to making policy decisions on coastal zone agricultural adaptation.

  In contrast to the outputs of these models, the actual productions of most coastal West African crops have showed a steady increase in yields over the past 10 years, and these crops have continued to maintain a dependable contribution to the GDP of each country. Also, the foregoing predictions on maize production in Ghana shown on Table 7 are inconsistent with a previous forecast from the Ghana Environmental Protection Agency, which estimated that the maize crops in Ghana will decrease by 6.9 percent due to climate change (Crawford, 2008).

- Therefore, more research is needed to identify the most realistic assumptions about social changes and adaptations that should be built into new models or back-calculated into existing models to avoid results that are inconsistent with actual data collected after model construction.

4.2 URBAN/PERI-URBAN

As previously noted, roughly 25 percent of the population in West African countries with a coastline lives in cities along the coast. There are very few cities in other parts of these countries; therefore, climate change impacts on the coastal areas of West African countries have the potential to affect large segments of the populations in these countries.

As stated in ECOWAS-SWAC/OECD (2008), "In West Africa, the areas most vulnerable to a rise in sea level or extreme incidents arising from extremely high tides and coastal surge have the highest population concentrations and are sometimes the most urbanized. There are 12 cities of over 500,000 inhabitants along the coastline... [see Figure 21]. The cities and their elevations are shown in …[Table 8]. Furthermore, productive ecosystems (mangrove swamps, deltas and estuaries) provide for significant economic activities in the fishing, farming and tourism sectors. The rise in sea levels has had direct impacts on these areas, including: submergence and coastal erosion, an increase in flood-prone areas and increase in salinity in estuaries and coastal water tables….(see [Figure 21], example of Banjul). Without policies on adapting to these changes, a 0.5 meter rise in sea levels by 2100 will lead to further direct loss of coastal lands through submergence."

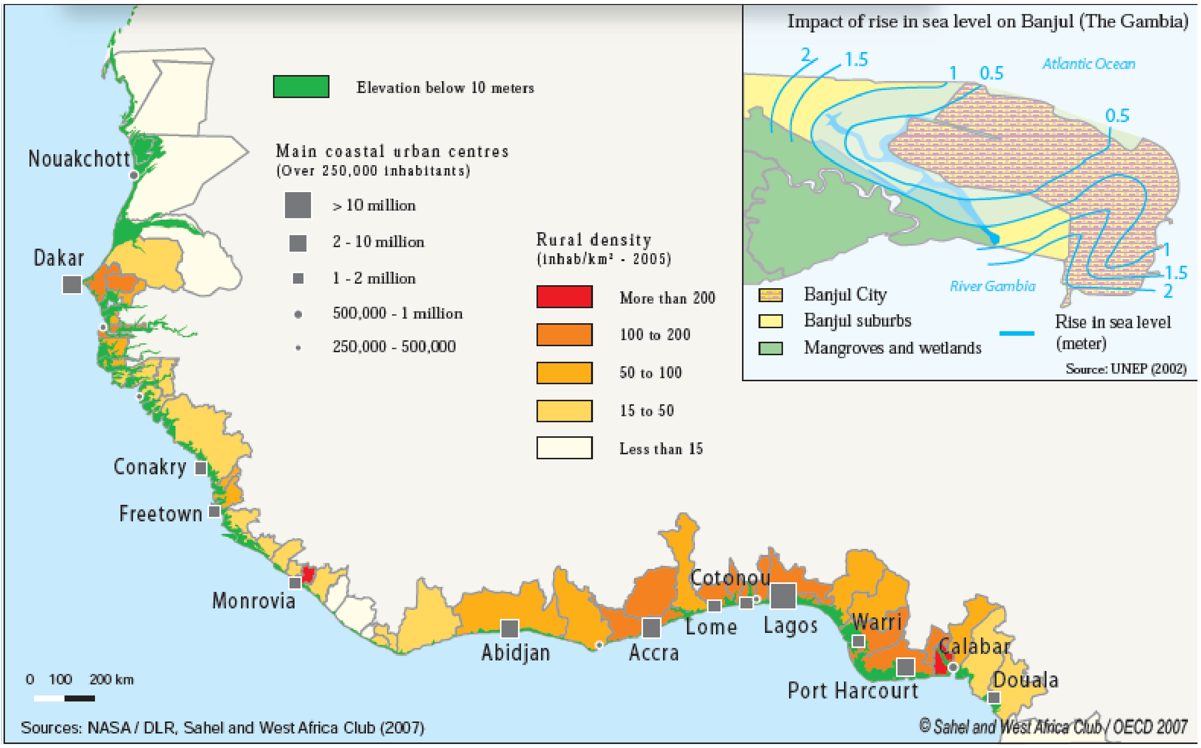
TABLE 8. POPULATION AND ELEVATION OF MAJOR WEST AFRICAN CITIES

City	Country	City Population	City Pop Rank [World]	City Pop Rank [Africa]	Elevation
Lagos	Nigeria	8,029,200	15	1	Below sea-level to 7m
Abidjan	Cote d' Ivoire	3,310,500	51	6	18m avg.
Dakar	Senegal	2,384,000	80	14	12m avg.
Accra	Ghana	1,605,400	132	22	91m avg.
Conakry	Guinea	1,595,800	134	24	13m avg.
Douala	Cameroon	1,239,100	193	27	13m avg.
Port Harcourt	Nigeria	1,053,900	255	36	18m avg.
Freetown	Sierra Leone	1,032,100	260	38	26m avg.
Cotonou	Benin	761,900	364	52	51m avg.
Lome	Togo	675,000	423	61	64m avg.
Monrovia	Liberia	543,000	538	71	23m avg.
Warri	Nigeria	500,900	609	83	5m avg.

Source: ECOWAS-SWAC/OECD, 2008

As discussed in Boko (2007), "The projected rise in sea level will have significant impacts on these coastal cities because of the concentration of poor populations in potentially hazardous areas that may be especially vulnerable to such changes (Klein et al., 2002; Nicholls, 2004). In very recent assessments of the potential flood risks that may arise by 2080 across a range of SRES scenarios and climate change projections, three of the five regions shown to be at risk of flooding in coastal and deltaic areas of the world are those located in Africa, including: North Africa, West Africa, and southern Africa (see Nicholls and Tol, 2006; for more detailed assessments, see Warren et al., 2006)."

FIGURE 21. VULNERABLE COASTAL CITIES OF WEST AFRICA



Source: OECD, 2007

To better understand the potential impacts to the urban and peri-urban environment, the following sectors are discussed:

- Building Materials and Practices
- Water
- Services
- Transport
- Tourism
- Insurance

This overview describes generic issues facing West Africa urban and peri-urban areas. To better understand specific urban contexts and vulnerability to climate change, more detailed assessments are necessary on priority cities.

4.2.1 Building Materials and Practices

Building practices vary across the region, depending on the country's history, available building materials, and construction knowledge. Mud and clay are commonly used in rural locations across West Africa, and these materials are still used in some peri-urban residential areas. The clay in residential areas is usually formed into bricks and dried in the sun to make adobe. As a building material, mud is not very durable and tends to crack at high temperatures and erode in downpours. It does keep a house cool during the day in hot weather and warm in the night when temperatures drop, is easy to repair, easily available, and requires no special tools.

In urban areas, concrete block and corrugated metal are common building materials. Iron corrugated metal and sawn timber beams used to support the metal are poor building materials (both thermally and acoustically); also, the use of timber beams accelerates deforestation. In urban centers, reinforced and unreinforced masonry is common depending on the city and building use – government, religious, residential, tourist hotel, etc.

In addition to issues with building materials, a number of issues arise from current building practices and skill levels. Building materials and practices of concern include the following:

TABLE 9. BUILDING MATERIALS AND PRACTICES OF CONCERN

Building Materials, Practices, and Resource Limitations	Examples of Ties to Climate Change Vulnerability
Lack of master tradespeople	• Questionable structural integrity of buildings; not able to withstand flooding or strong winds • Hazard considerations not integrated into building location and construction material planning
Non-sustainable building practices (e.g., using wood to create fired bricks; using sawn timber beams causing deforestation)	• Non-sustainable practices further expose buildings and surrounding land (e.g., trees serve as natural protection to reduce wind speeds during typhoons) • Deforestation increases climate change
Non-regulated, illegal building	• Low-quality structures are less able to withstand hazards • Buildings in low-lying or otherwise exposed areas • Lack of, or limited, water supplies that are exposed to inundation/pollution
Corruption and lack of enforcement	• Same as above
Lack of suitable building material	• Structures not hardened for coastal conditions are less able to withstand hazards • Non-sustainable practices further exacerbate climate change and hazard impacts (erosion, etc.)

Climate change can impact buildings in several ways. Direct damage can result in structures exposed to current and future sea-level rise, storm surge inundation areas, storm winds, and flooding. People inside the structures may also be impacted more by extreme temperatures if the building construction practices do not help to protect the inhabitants and cooling systems are not available or adequate. Also, building in vulnerable areas can impact residents through fouling of water (e.g, saltwater intrusion) or submersion or failing of infrastructure (power, septage, public water supply, etc.).

Adaptation strategies that may be implemented include:

- Integrating water capture into the building design (rain and greywater);
- Using water tanks to cool and heat a structure;
- Educating builders on disaster-resistant construction practices – location of buildings, structure-foundation strengthening or elevation; shuttering of windows; enhanced roof/wall connections; material selection; etc.;
- Identifying innovative building-design techniques (e.g., tie downs or fastening for oil tanks or generators); and

- Delineating flood-prone areas and designating these for public use (parks), rather than building uses
- For example, in regards to materials selection, clay is very susceptible to water events, but clay with a rock or concrete foundation would be less vulnerable. Fired bricks are also less vulnerable, but firing could have a disadvantage as the only source of heat for firing is burning the wood from forests.

4.2.2 Water

West Africa's water resources include surface water that is governed by irregular precipitation, local runoff, and infiltration; and subsurface water that is governed by geology and climate. During the dry season, most rivers dry up, including the major basins. Since there are so many aquifers in the region, generalizations about groundwater availability are difficult. The three largest cross-border aquifer systems are the Chad Basin (Niger, Nigeria, Chad, and Cameroon); the Lullemeden Basin (Niger, Nigeria, Mali, Algeria, and Benin); and Senegalo-Mauritanian Basin (Senegal, Mauritania, the Gambia, and Guinea-Bissau).

Most of West Africa currently has adequate water resources to meet the needs of the population, including the agricultural and industrial sectors. A "water stress index," based on the approximate minimum amount of water per person (36.5 cubic meters per year) necessary to maintain an adequate quality of life in a moderately arid zone, was developed by Falkenmark (1989). This index also established that roughly five to 20 times this amount would meet the requirements of agriculture, industry, and energy production. Hydrologists designate water-scarce countries as those with an annual freshwater availability of less than 1,000 cubic meters per person per year, and water-stressed countries as those with an annual freshwater availability of 1,000 to 1,667 cubic meters per person per year. Based on the information provided in Table 10, only Cape Verde would be considered water-scarce and only Nigeria would be considered water-stressed.

TABLE 10. WATER RESOURCES BY WEST AFRICAN COUNTRY

Country	Water Resources–Renewable (cu km)	Withdrawal (dom, ind, ag)	Withdrawal Per Capita	Population	Water Available Per Capita (cu m/ person/yr)
Cape Verde	0.3	0.02 cu km/yr (6 percent, 1 percent, 93 percent)	486 cu m/yr	531,046	564
Senegal	38.8	2.22 cu km/yr (4 percent, 3 percent, 93 percent)	221.6 cu m/yr	13,300,410	2,917
The Gambia	8	0.09 cu km/yr (41 percent, 21 percent, 39 percent)	65.8 cu m/yr	1,883,051	4,248
Guinea-Bissau	31	0.18 cu km/yr (18 percent, 6 percent, 76 percent)	135.7 cu m/yr	1,660,870	18,664
Guinea	226	0.55 cu km/yr (39 percent, 10 percent, 51 percent)	64.3 cu m/yr	11,176,026	20,221
Sierra Leone	160	0.21 cu km/yr (52 percent, 26 percent, 22 percent)	38.7 cu m/yr	5,612,685	28,506
Liberia	232	0.13 cu km/yr (55 percent, 37 percent, 8 percent)	43.7 cu m/yr	3,989,703	58,149

Country	Water Resources–Renewable (cu km)	Withdrawal (dom, ind, ag)	Withdrawal Per Capita	Population	Water Available Per Capita (cu m/ person/yr)
Cote d'Ivoire	81.14	1.55 cu km/yr (41 percent, 21 percent, 38 percent)	83.1 cu m/yr	22,400,835	3,622
Ghana	53.2	0.98 cu km/yr (24 percent, 10 percent, 66 percent)	48.8 cu m/yr	25,199,609	2,111
Togo	14.7	0.17 cu km/yr (63 percent, 3 percent, 34 percent)	33.5 cu m/yr	7,154,237	2,054
Benin	26.39	0.13 cu km/yr (32 percent, 23 percent, 45 percent)	18.7 cu m/yr	9,877,292	2,671
Nigeria	286.2	13.11 cu km/yr (31 percent, 15 percent, 54 percent)	89.2 cu m/yr	174,507,539	1,640
Cameroon	285.5	0.97 cu km/yr (23 percent, 10 percent, 68 percent)	58.9 cu m/yr	20,549,221	13,893

Source: CIA, 2011

Since there is generally sufficient water at a national level, one of the major problems facing West Africa lies in the realm of water-resource management. In highly populated areas, safe and reliable water may be an issue. Some of the non-climate stressors on water resources in these countries include:

- Poorly constructed or lacking infrastructure for water supply (e.g., municipal water treatment and distribution infrastructure);
- Lack of integrated water resources management and use (water laws; water rights; institutional
- structures; planning, management, and decision-making processes; access to drinking water and sanitary services; and transboundary conflicts);
- Absence of economic and legal policies to support sustainable development (management of water demands through pricing and incentives for conservation; valuation of water and water-related services; and economic impacts of pollution and resource over-exploitation);
- Inadequate access to technology and participation in decision-making (legal and administrative instruments that enable direct involvement of water users, government, and other stakeholders in water planning, development, and management);
- Non-implementation of strategies for financing and investing in water resources (water resources development projects; non-structural measures; and improvements in water resources management);
- Lack of access to information about improving water-resource management (mechanisms for sharing information, water technology, and management experiences between organizations and countries; promotion of appropriate technologies that support sustainable development; and public education and training) (Gordan, 1998); and
- Population growth creating additional demand in the coastal, urban, and peri-urban areas.

Climate change will cause the frequency and intensity of extreme hydrological processes and disturbances in the hydrological cycle to increase. Over recent decades, rainfall shortages of 20 percent have been documented and river flows have decreased 20 to 60 percent for major river systems (UNESCO, 2007) in West Africa. Other issues that are projected as feasible in association with climate change include:

- Reduction of number of rainy days and shorter rainy season;
- Greater variation in start times for the rainy season;
- Increase in runoff coefficient for small basins, proliferation of invasive vegetation due to reduced flows, warmer water, and eutrophication;
- Reservoirs not filled during rainy seasons;
- Hydroelectric dam disturbances due to increased flooding or low water situations;
- Increase in evapotranspiration;
- Saltwater intrusion into lagoons and groundwater supplies;
- Drop in the water table; and
- Deterioration in water quality.

Current water-resource data gaps in the West Africa that need to be improved to better predict localized climate change impacts on water resources include:

- Non-availability of hydrological and hydro-geological data of sufficient quantity and quality (most not more than 30 years);
- Inadequacy of physical collection and storage of data (quality of infrastructure poor, coverage is not sufficient, and controls are not computerized);
- Detailed surveys of water-resource systems are not available; and
- Absence of climate and hydrological forecasting.

Despite these limitations that affect the ability to project climate impacts on water resources, there are a number of responses on the coastal zones that are likely to be "low-regret" adaptation opportunities. Climate change adaptation responses for water resources could include:

- Dedicating resources to the collection of meteorological, hydrological, socioeconomic, and environmental data;
- Supporting research on the uncertainty associated with climate models;
- Implementing water-demand studies across time horizons that climate change will occur;
- Developing effective water-management programs;
- Promoting integrated management of water resources; and
- Building capacity for water-resource managers in the region.

4.2.3 Utilities

The state of the current West African utilities is shown in Table 11. Many countries use fossil fuels to produce their electricity, although quite a few are also using hydropower. Oil producers (Senegal, Sierra Leone, Côte d'Ivoire, Ghana, Nigeria, and Cameroon) and natural gas producers (Senegal, Cote d'Ivoire, Nigeria, and Cameroon) are also shown. The 678-kilometer West African Gas Pipeline moves gas from Nigeria through the waters of Benin, Togo, and Ghana, approximately 15 to 20 kilometers offshore at depths from 30 to 75 meters. It has a capacity to move five billion cubic meters (bcm) of natural gas per year. Countries with access to improved sanitary management and water supplies are shown for the nation level. Urban coastal centers typically have a higher percentage of infrastructure than rural areas.

TABLE 11. WATER RESOURCES BY WEST AFRICAN COUNTRY

Country	Imp. Water	Imp. Sanitation	Natural Gas	Oil (Crude; Refined)	Hydropower*	Fossil Fuels*	Alt.*	Total Energy*
Cape Verde	88 percent	61 percent	----	----	----	96.90 percent	3.10 percent	277 million kWh
Senegal	76 percent	57 percent	50 million cu m	0; 16,850 bbl/day	----	99.70 percent	0.30 percent	2.608 billion kWh
Gambia	89 percent	68 percent	----	----	----	100 percent	----	240 million kWh
Guinea-Bissau	64 percent	20 percent	----	----	----	100 percent	----	65 million kWh
Guinea	74 percent	18 percent	----	----	31.30 percent	68.70 percent	----	955 million kWh
Sierra Leone	49 percent	13 percent	----	0; 4,381 bbl/day	7.70 percent	92.30 percent	----	120 million kWh
Liberia	73 percent	18 percent	----	----	----	100 percent	----	335 million kWh
Cote d'Ivoire	80 percent	24 percent	1.6 billion cu m	45,000 bbl/day; 70,870 bbl/day	49.40 percent	50.60 percent	----	5.533 billion kWh
Ghana	86 percent	14 percent	----	72,580 bbl/day; 27,260 bbl/day	59.40 percent	40.60 percent	----	8.764 billion kWh
Togo	61 percent	13 percent	----	----	78.80 percent	21.20 percent	----	Top of Form 123 million kWh Bottom of Form
Benin	75 percent	12 percent	----	----	1.70 percent	98.30 percent	----	120 million kWh

Country	Imp. Water	Imp. Sanitation	Natural Gas	Oil (Crude; Refined)	Hydropower*	Fossil Fuels*	Alt.*	Total Energy*
Nigeria	54 percent	35 percent	29 billion cu m	2.525 million bbl/day; 102,100 bbl/day	32.90 percent	Top of Form 67.10 percent Bottom of Form	----	18.82 billion kWh
Cameroon	74 percent	47 percent	20 million cu m	61,580 bbl/day; 42,520 bbl/day	72.20 percent	27.80 percent	----	5.589 billion kWh

Cu m=cubic meters; bbl=oil barrel; kWh=kilowatt hours. Source: CIA, 2009; CIA, 2011.*

Specific concerns have been raised regarding saltwater intrusion irrespective of climate change as growing urban populations draw down coastal aquifers. Various studies have been undertaken in Nigeria (Oteria and Atolagbe, 2003; Oyedele and Momoh, 2009); Cameroon (Folack, ND), Benin (Silliman et al., 2010), Togo (Akouvi, 2008), Ghana (Kortatsi and Jorgensen, 2003; BGR-GSD, 2006; Mensah and FitzGibbon, 2012), Côte d'Ivoire (Jallow et al., 1999); Guinea (Wolanski and Cassagne, 2000); the Gambia (Jallow et al., 1999); and Senegal (Faye et al., 2005; Niang et al., 2010). Some of these document current intrusion (Oteria and Atolagbe, 2003; Silliman et al., 2010; Kortatsi and Jorgensen, 2003; Oyedele and Momoh, 2009; Wolanski and Cassagne, 2000), while others use modeling to predict the quality of water sources over the coming decades or century (Jallow et al., 1999; Silliman et al., 2010; Folack, ND; Mensah and FitzGibbon, 2012; Varis and Farboulet-Jussila, 2010; Niang et al., 2010). The majority of these find limited data and the location-specific dynamics of intrusion as constraints to generalizing risk. While most of these studies find that intrusion of saltwater is a factor in the coastal aquifer water quality, few attempt to consider the relative role of climate change in this process. Urban water quality will continue to be a central development challenge along the West African coast, and a greater understanding of these coastal aquifers is certainly necessary.

The current stressors acting on the utility services in West Africa include:

- An increasing population to serve;
- Piracy (in 2012, a pirate vessel damaged the West African Gas Pipeline, causing extensive losses) and other pipeline attacks;
- Corruption, resulting in high cost and inadequate utility performance;
- Lack of access for large parts of the population;
- Rising fuel costs;
- Antiquated power plants;
- Regulation issues; and
- Difficulty in collecting payment from public customers.

Climate change will cause several impacts for each utility type. Examples of these impacts include:

- Additional water storage required to maintain water during periods of erratic precipitation;
- Water demand may go up, due to increased temperatures and drought conditions;

- Pipe systems for both drinking-water supply and sewerage will be more prone to cracking, as climate changes lead to greater soil movement as a consequence of wetting and drying cycles;
- Assets on the coast or in flood plains (that covers most of them – networks, water, and wastewater-treatment works, pumping stations) will be at increased risk from flooding, storm damage, coastal erosion, and rises in sea levels;
- Existing sewerage systems were not designed to take climate change into account. This means that more intense rainfall is likely to exceed the capacity of parts of the network and cause local flooding;
- Dams will be more prone to siltation resulting from increased soil erosion, and the slippage risk to soil dams from intense rainfall events will also increase;
- Lower river flows will reduce the dilution of wastewater effluent;
- Color and odor problems could result from higher temperatures and more intense rainfall events;
- Oil infrastructure may be damaged due to storm events, causing major environmental damage;
- Oil boats using the waterways may run aground if the water levels get too low; and
- Hydropower water requirements may not be met, especially once other water demands are considered.

Within each relevant industry, there are clear risks posed by climate change. One can assume that for industries with large levels of international investment, climate change has been considered as a risk factor at some level. Nevertheless, the number of international companies and local subcontractors that are being engaged to work on new infrastructure would suggest that there are many actors involved in construction of new infrastructure that are not engaged in climate change risk planning.

Adaptation strategy recommendations include:

- Conduct detailed climate vulnerability and risk assessments for each utility, including evaluating proposed locations of future utility facilities;
- Integrate climate change into any capital improvement plans for each city. If infrastructure is being financed by multilateral banks, ensure climate change is included in the environmental site assessment or as a separate study;
- Develop new, and support existing, relationships between service providers in order to set up mutually beneficial agreements in case of drought or other disasters;
- Ensure utility companies, including oil and gas companies, have emergency operations plans, have incorporated local input into these plans, and have accounted for climate change; and
- New construction should include disaster-resistant building practices focused on flooding and storm surge events.

4.2.4 Transportation

Much of the transportation infrastructure in West African countries is located along the coast. The major ports in West Africa include: Port of Dakar (Senegal), Port of Abidjan (Cote d'Ivorie), Port of Tema (Ghana), Port of Cotonou (Benin), Tin Can Island Port (Nigeria), Port of Apapa (Nigeria), Port of Port Harcourt (Nigeria), Port of Onne (Nigeria), and Port of Douala (Cameroon). The ports support the importation of consumer goods, foodstuffs, motor vehicles, machinery, and industrial raw materials and the export of timber, agricultural products, and oil. There are several smaller ports included in Table 11 below.

All of the West African countries have airports located on the coastline, and most of the major airports are located adjacent to the water. Many of the major roadways are paved and located on the coastline connecting the urban centers. Rail is found on the coastline and is used in conjunction with the ports, airports, and major urban areas. Transportation is a key component of West Africa's current trade and potential growth. Table 12 shows total roads, paved roads, rail, airports, and ports. It also indicates how many of the airports lie in the coastal area.

TABLE 12. WEST AFRICAN TRANSPORTATION

Country	Total Roads (km)	Paved (percent)	Rail (km)	Airports (On Coast)	Ports
Cape Verde	10,000	53.0	0	8 (8)	9
Senegal	14,825	32.0	906	13 (2)	7
Gambia	3,742	19.3	0	1 (1)	2
Guinea-Bissau	4,400	37.8	0	1 (1)	4
Guinea	30,500	34.6	1086	14 (2)	3
Sierra Leone	11,700	8.0	84	8 (2)	4
Liberia	10,600	6.2	0	10 (7)	4
Cote d'Ivoire	50,400	7.9	660	27 (4)	5
Ghana	40,186	16.2	935	8 (3)	2
Togo	7,520	21.0	568	7 (1)	2
Benin	6,787	9.5	578	7 (1)	2
Nigeria	194,394	15.0	3557	46 (4)	6
Cameroon	50,000	17.0	987	38 (4)	5

Source: CIA World Factbook, 2011; World Bank, 2010

The road infrastructure in West Africa is in poor condition and lacks the capacity to handle the ever-increasing traffic. Many trucks are overloaded, which damages the roads and bridges and cuts the road's lifespan in half. Weigh stations are used to collect fines instead of looking after the road conditions.

Air transport is a more reliable way to move goods, but the costs are very prohibitive. Rail was in a poor state in the early 2000s, with disuse and civil war damaging many kilometers of line during this period in some countries. With a new push to export mineral wealth, mining companies have been investing in rail projects leading from the interior to the ports. Port efficiency has been a problem at several West African ports, slowing down transport times and causing monetary losses due to inefficiencies. Large ships do not visit West African ports due to limited traffic, poor facilities, and a lack of maintenance dredging (Harding, 2007).

Transportation infrastructure is expected to be affected by sea-level rise, coastal flooding, and surge inundation because most of the roads, airports, train-rail networks, and ships are located in and near the major cities that line the coasts of West African countries. Climate-change-related impacts could destroy infrastructure, close infrastructure causing delays, delay transportation of goods, damage goods in transit, and delay international relief if airports or ports are damaged during a storm event.

Some of the information gaps include a lack of vulnerability and risk assessment information at the site level for ports, airports, and major transportation arteries; a lack of port contingency plans; and limited understanding or modeling of potential climate change impacts at the local level.

Potential climate change adaptation strategies for transportation include:

- Integrating climate change planning into transportation planning; considering evacuation routes for severe storms; placing replacement roads on higher ground when low-lying roads subject to chronic flooding are upgraded over time; and building bridges at an appropriate elevation while evaluating and eliminating scour potential.
- Including sea-level rise estimates into new and existing port plans; also, as ports need to be built larger to handle more traffic and larger ships, integrate sea-level rise estimates into the construction documents.
- Developing port and airport contingency plans; put plans in place for severe storms, make sure everyone understands the plan and it is exercised, and consider regional partnerships with other ports.
- Develop focused, site-level adaptation plans, including climate risk assessments, for major transportation hubs.

4.2.5 Tourism

Although tourism is not a major industry for West Africa, it does have potential, and many of the biggest tourist destinations are located on the coastline. As noted in Boko (2007), "Climate change could also place tourism at risk, particularly in coastal zones and mountain regions." Important market changes could also result from climate change (World Tourism Organization, 2003) in such environments. Table 13 describes the current number of tourists and the value of the tourist industry per year for each country.

TABLE 13. WEST AFRICA TOURIST INDUSTRY, 2011

Country	Tourists	Value
Cape Verde	428k	$438.0M
Senegal	1001k	$464.0M
Gambia	106k	$102.0M
Guinea-Bissau	30k	$13.6M
Guinea	30k	$2.1M
Sierra Leone	52k	$44.0M
Liberia	NA	NA
Cote d'Ivoire	270k	$213.0M
Ghana	931k	$797.0M
Togo	300k	$105.0M
Benin	209k	$187.6M
Nigeria	715k	$688.0M
Cameroon	573k	$171.0M

Source: World Tourism Organization, 2011

Some popular coastal tourist destinations include:

- Goree Island (*Ile de Goree*) is a small, tranquil island just off the coast of Dakar. The island was a major slave-trading center and includes the *Maison des Esclaves* (House of Slaves), built by the Dutch in 1776 as a holding point for slaves. There are museums and a jetty lined with fish restaurants.
- Ganvie in Benin is a village built on a lake, close to the capital of Cotonou. All of Ganvie's houses, shops, and restaurants are built on wooden stilts several feet above the water.
- Ghana's coast is lined with old forts (castles) built by various European powers during the 17th century. Many of these forts are now museums and tourist destinations.
- The Sine-Saloum Delta lies in the southwest of Senegal. It is a large area of mangrove forests, lagoons, islands, and rivers, and a popular tourist destination.
- Several of the major cities along the coast have music, dancing, casinos, tourist hotels, and water sports.

These coastal tourist sites may benefit from locally specific climate change vulnerability assessments alongside their site-specific growth strategies.

Much of the tourist value in Table 12 could be at risk in the future, due to a range of pressures that could be exacerbated by climate change stressors. Climate change is likely to play a relatively minor role in the near-term constraints to growth of the tourism sector, as there are a variety of factors that are limiting the sector development, including:

- A reputation for inefficient health care, human-rights abuses, and safety issues;
- A highly fragmented industry (travel agencies, tour operators, carriers, hoteliers, and restaurateurs);
- Tourism is very seasonal, creating periodic pressures in the tourist areas and requiring infrastructure investment for a short period of time. Seasonal workers employed by the industry often lack the necessary skills and, on some occasions, do not enjoy fair working conditions, salaries, and career opportunities;
- A history of natural disasters, crime, poverty, and insecurity; and
- Significant increases in environmental pollution and degradation of the natural environment. The most relevant pressures come from transport, the use of water and land, the use of energy by tourism building facilities, the generation of waste, the erosion of soils, and the loss of biodiversity.

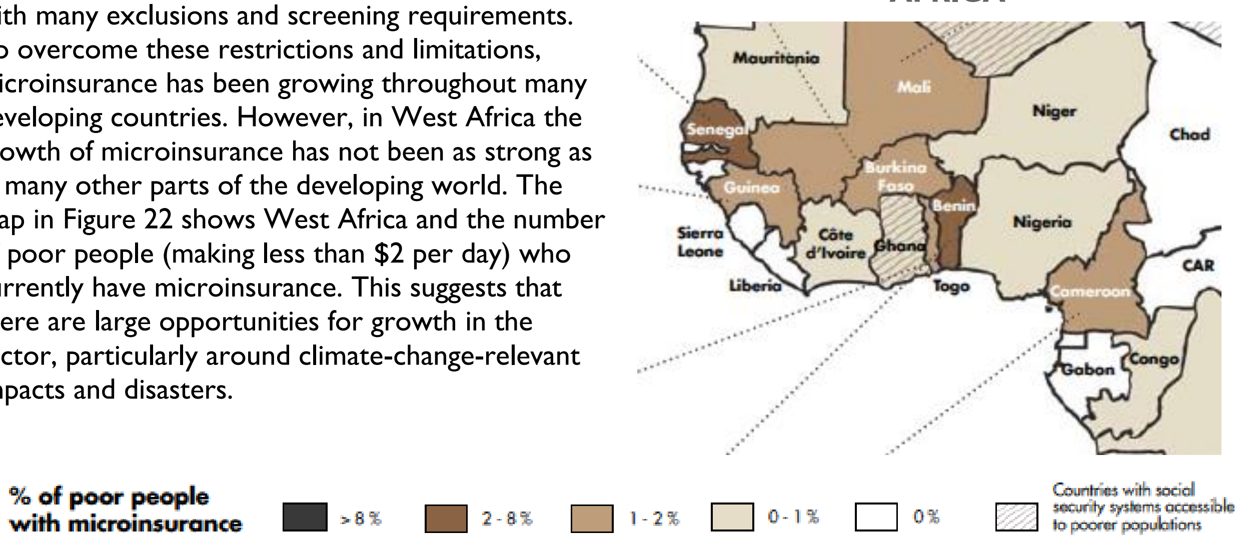
For the most part, adaptive strategies within the tourist industry reflect improved planning and sector coordination, which should be done regardless of climate change threats. As the sector matures, both through the growth of regional tourism and international tourism, adaptation strategies that may be implemented include:

- Integrating tourism into regional or local planning efforts. Tourism could be a larger industry, but should be grown sustainably.
- Developing tourist preparedness plans to prepare for severe storms or flooding. These would also reassure tourists that their safety is a primary concern.
- Identifying "at-risk" historical sites and developing preparedness plans to ensure they survive future climate conditions.

4.2.6 Insurance

Traditional insurance is not designed for low-income groups since it has commission caps, a focus on large policies, strict payment plans, and complex policies with many exclusions and screening requirements. To overcome these restrictions and limitations, microinsurance has been growing throughout many developing countries. However, in West Africa the growth of microinsurance has not been as strong as in many other parts of the developing world. The map in Figure 22 shows West Africa and the number of poor people (making less than $2 per day) who currently have microinsurance. This suggests that there are large opportunities for growth in the sector, particularly around climate-change-relevant impacts and disasters.

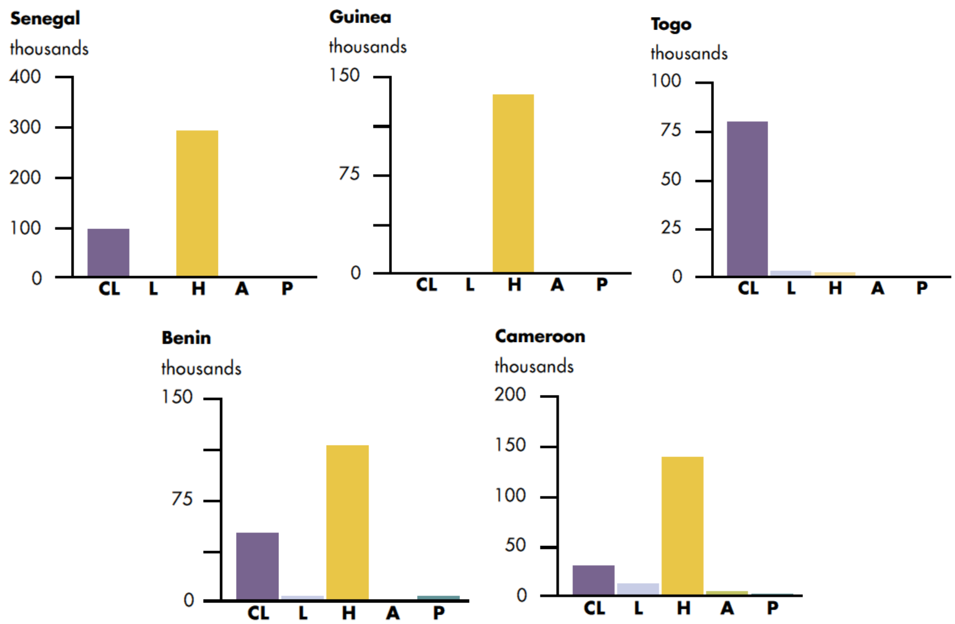
FIGURE 22. ACCESS TO MICROINSURANCE IN WEST AFRICA



Source: Matul, 2009

Microinsurance can include credit, life, health, agriculture, and property insurance. Weather index insurance has also been advocated as a solution, particularly for farmers in areas affected by droughts and floods. Donors are experimenting with weather index insurance in Senegal, although uptake of insurance remains limited. Current microinsurance coverage in some of the West African countries is shown in Figure 22. Credit life and health coverage are very popular in the region, but each country is different depending on the product marketing strategies (Figure 23).

FIGURE 23. VALUE OF INSURANCE INVESTMENTS ACROSS A SUBSET OF WEST AFRICAN COUNTRIES



Note: CL=Credit Life; L=Life; H=Health; A=Agriculture; P=Property

There are several factors limiting how many people currently have cost-effective microinsurance, including:

- High administration fees;
- Lack of education and outreach;
- Too few risk carriers;
- Regulatory and legal framework issues;
- Limitations on health care provision and quality;
- Lack of risk data; and
- Capacity building of stakeholders to develop, sell, and manage better products.

For the people living on less than a dollar a day who depend on agriculture for their livelihoods, climate-related shocks are a constant threat to their food security and well-being. As climate change brings an increase in the frequency and intensity of droughts and storms, the challenges faced by food-insecure communities will also increase. If the number of disasters goes up, insurance premiums also will rise; this will prevent many from being able to afford insuring their property, agriculture, and lives. It should be noted that insurance is a way to transfer risk and it does not eliminate losses, but spreads the loss over a pool of people. If the losses become too great for a region, the private sector will not provide insurance. This is potentially a concern with respect to coastal infrastructure insurance, as many areas on the coast may become uninsurable. Nevertheless, it is worth exploring insurance opportunities for urban and peri-urban populations in the coastal zone of West Africa.

Efforts to support microinsurance offering through West Africa include:

- Educating and training potential providers;
- Developing better risk data, including climate change exacerbated risk;
- Creating outreach programs for the poor; and
- Working towards common regulatory and legal frameworks region-wide.

While these services will undoubtedly grow with the growth of economic opportunities in the region, USAID and other donors may need to help prime the opportunities related to climate risk.

5.0 OVERVIEW OF INSTITUTIONAL CHALLENGES

5.1 BACKGROUND

Climate change is placing new, unanticipated pressures on West African coasts, areas that are already experiencing stressed ecological systems and rapidly changing socioeconomic dynamics. At present, the pressures of urban development, rush for resources, and challenges of carrying out and enforcing land-use planning dominate development along the coast. The lens of climate change offers the opportunity to integrate medium- and long-term risk into coastal planning and development. Coastal and marine issues are priorities within the climate change considerations across West African countries (Table 14). Yet, by 2012, despite the prioritization of coastal issues across West African countries, only six of the countries (the Gambia, Guinea, Guinea-Bissau, Nigeria, and Senegal) had begun undertaking adaptation actions. For the most part, from Senegal to Cameroon, national institutions are currently limited in their ability to engage in coastal adaptation activities, which makes transboundary and regional collaboration particularly challenging. But there are some institutions that are beginning to gain traction on climate-resilient development in West African coastal areas.

TABLE 14. COMPARISON OF PRIORITY SECTORS FOR ADAPTATION AS IDENTIFIED IN NATIONAL COMMUNICATIONS TO THE UN FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC) AND NATIONAL ADAPTATION PROGRAMS OF ACTION

	Agriculture	Livestock	Fisheries	Forestry	Freshwater	Coastal	Health
Benin	x				x	x	x
Cameroon	x					x	x
Cape Verde	x				x	x	
Cote d'Ivoire	x				x		x
The Gambia	x		x		x	x	x
Ghana	x				x	x	
Guinea	x			x	x	x	
Guinea-Bissau	x	x	x	x	x	x	x
Liberia	x		x	x			x
Nigeria	x				x	x	x
Senegal	x	x	x	x	x	x	x
Sierra Leone	x		x	x	x	x	x
Togo	x				x	x	x

This section analyzes opportunities for transboundary and regional collaboration on a range of coastal issues through the lens of climate change impacts. It describes barriers and opportunities for regional collaboration in West Africa, necessary institutional roles for successful adaptation, and considers the human and institutional capacities of a set of regional and global institutions that may engage in coastal management and climate change in West Africa. The paper explores these capacities as they relate to the institutional roles of assessment, prioritization, policy development and coordination, implementation, and information management, adapting the World Resources Institute's National Adaptive Capacity framework as an entry point. The analysis considers country-level capacity, regional concerns, and individual institutions that have the potential to engage at a regional level. Given that this assessment was largely desk-based, the list of national and regional institutions is undoubtedly incomplete and the assessment of capacities is open to more nuanced interpretations of capacities, as well as new institutions.

A central question in understanding climate change vulnerability in coastal West Africa and the appropriate institutional response is the extent to which limited action regarding climate change impacts on West African coasts is related to:

- A lack of understanding of the impacts;
- A lack of understanding of appropriate climate change adaptation responses; and/or
- An explicit prioritization of more urgent and pressing threats to ecosystems and economic growth in the region.

Each of these factors likely plays a role in the regional institutional response to climate change adaptation. The Guinea Current Large Marine Ecosystem (GCLME) Transboundary Diagnostic Assessment explicitly notes the need to better quantify the impact of climate change on coastal resources (IGCC, 2006). This is further evidenced in the National State of the Coast reports completed under the Abidjan Convention, where countries generally described hypothesized climate impacts on a wide range of sectors, but in very abstract and unspecific ways. Interestingly, while these State of the Coast reports generally describe some climate impacts, they rarely included specific adaptation measures, and if they do, the adaptation measures only weakly address the described climate impact.

5.1.1 Defining the Role of Climate Change

Understanding the potential role of climate change over the coming decades in the development challenges facing West African populations is of fundamental importance to assessing institutional capacities. According to the GCLME Transboundary Diagnostic Assessment (ICGG, 2006), there are four major perceived transboundary coastal-management challenges affecting the West African coastal zone:

- Decline in fish stocks and non-optimal harvesting;
- A loss of ecosystem integrity, including from the effects of climate change;
- Deterioration in water quality; and
- Habitat destruction of seabed and coastal zone, including coastal erosion.

These challenges are directly caused by a collection of stressors, of which climate change is a subset. The non-climate stressors leading to these challenges are significant and, in most cases, are greater and more imminent than climate stressors. For example, significant non-climate stressors include:

- Illegal, unreported, and unregulated fishing (IUU);

- The physical destruction of coastal habitats;
- Population growth and migration to coastal areas;
- Uncontrolled urbanization;
- Untreated sewage and industrial waste dumping;
- Risks from pesticide use and petroleum pipeline development and use;
- Construction of new harbors and coastal infrastructure;
- Sedimentation from rivers; and
- Apparent increases in the frequency and extent of coastal erosion.

These stressors may be specific to individual sectors (such as the impact of IUU fishing on fishery populations), while other stressors, such as coastal infrastructure, may have broad-reaching cross-sectoral impacts, or may have positive or negative impacts. A variety of priority vulnerable sectors have been identified in the State of the Coasts reports and national coastal strategies prepared by West African countries for the Abidjan Convention and under the GCLME, including tourism, agriculture, salt and sand production, aquaculture, maritime transport, fishing, mining and petroleum, industry, forestry, and livestock.

Climate stressors interact with the above non-climate stressors to cause specific challenges. While some of the above stressors are perhaps more imminent than climate stressors, this does not limit the centrality of considering climate change in West African coastal planning, in part because the climate stressors are expected to intensify through time, and a failure to consider them may result in maladaptation. In the context of a rapidly developing coast, siting infrastructure in future vulnerable areas, without consideration of climate impacts, may result in enormous financial and human costs. While projections of specific climate impacts on the West African coast are weak, particular climate impacts of concern include:

- Temperature impact on upwelling and fisheries;
- Sea-level rise;
- Salinization of coastal land;
- Flooding;
- Coastal erosion;
- Saltwater intrusion;
- Toxic algal events;
- Coastal eutrophication and hypoxia; and
- Extreme event impacts on infrastructure.

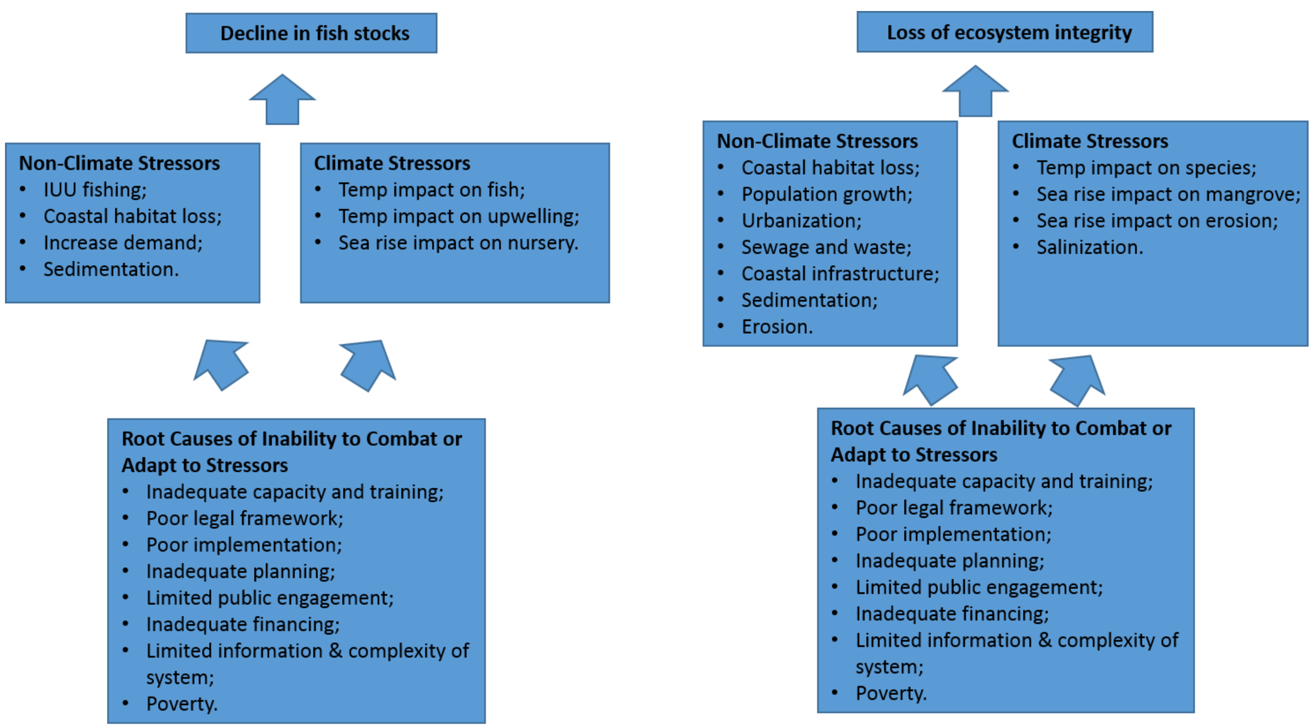
In the case of both climate and non-climate stressors, the root cause of society's relative inability to combat non-climate stressors and plan and adapt to climate stressors are related to:

- Inadequate capacity and training;
- Poor legal framework;

- Inadequate implementation of regulations;
- Inadequate planning at all levels;
- Insufficient public involvement;
- Inadequate financial mechanisms;
- Inadequate information for effective decision-making;
- The complexity of the ecosystems; and
- Poverty (ICGG, 2006).

These root causes are primarily institutional, and are undoubtedly at the core of many of the development challenges facing West Africa. Each of these root causes limits the potential success of adaptation activities. As a result, climate change investments must address these structural challenges afflicting a large number of West African institutions. Indeed, existing adaptation programs tend to address capacity, public involvement, poverty, and ecosystem restoration, yet for the most part these have been undertaken at a small scale. Where these challenges are not addressed directly, practitioners should take action to ensure that these root causes don't undermine the success of broader interventions (Figure 24).

FIGURE 24. EXAMPLE OF RELATIONSHIPS BETWEEN ROOT CAUSES, CLIMATE, AND NON-CLIMATE STRESSORS AND CRITICAL COASTAL CHALLENGES FACING WEST AFRICA



5.1.2 Transboundary and Regional Issues

Opportunities for coordination on coastal-management activities at a transboundary or regional level are driven by the scale of each issue. Some management issues are regional in nature (for example, fisheries associated with the Canary Current or the Guinea Current), while others are relatively local in scale but still cross national boundaries (for example, the impacts of coastal construction in Benin on beach erosion and accretion in Togo). Finally, there are a number of coastal-management issues that are primarily national management issues, such as freshwater availability in coastal communities. Both Senegal and Ghana face issues with respect to urbanization, salinization of agricultural fields, saltwater intrusion, and coastal erosion, and may benefit from sharing lessons on their responses, but the benefits of active collaboration on combatting these issues, and thus the incentive to invest in collaboration, may be limited.

The movement from sharing lessons to coordination of activities to active collaboration requires progressively greater investment from relevant actors. As opportunities are sought to promote these transboundary efforts, it is important to evaluate the scale of the challenge at hand and the costs and benefits of each of these progressive levels of engagement. In most cases, the sharing of lessons on coastal management and climate change impacts is likely to be a relatively low-cost, high-benefit activity for national governments and stakeholder groups in West African countries, while active collaboration on responses may be more costly and less necessary.

All West African countries have bilateral process with neighboring countries on specific transboundary issues. This assessment does not examine each of the 11 bilateral coastal environmental relationships between West African countries from Senegal to Cameroon. Discussions with representatives in Benin, Côte d'Ivoire, and Guinea suggest that in many cases these relationships exist, but in practice they vary depending on the severity of the issue. For example, the impacts of port development on coastal erosion in Lome and Contonou are issues that have led to significant bilateral discussions, whereas coastal transboundary issues are much less pressing between the rural communities on the Côte d'Ivoire/Liberia border (other transboundary issues are extremely contentious along this border). As a result, opportunities for transboundary collaboration and coordination on policy and implementation are largely based around specific local issues (Table 15).

While active management collaboration may not always be feasible at a regional level, the development of regionally relevant information (for example, data collection and analysis related to climate or biophysical information) and human and institutional capacity are clear areas where regional collaboration and coordination can result in significant dividends. Yet despite these opportunities, West Africa does not have a strong history of open data sharing, and this needs to be addressed in coastal and climate change collaboration going forward.

Table 15 presents a list of potential relationships and coastal transboundary issues that will affect neighboring countries in West Africa. These relationships should be further explored, both by validating whether they are the most significant transboundary coastal challenges, and then by assessing the relative role of climate change in these relationships.

TABLE 15. POTENTIAL RELATIONSHIPS AND COASTAL TRANSBOUNDARY ISSUES AFFECTING NEIGHBORING COUNTRIES IN WEST AFRICA

Transboundary Border	Hypothesized Transboundary Management Priorities
Senegal/Gambia	Fishery management, Freshwater
Senegal/Guinea-Bissau	Mangrove/Ecosystem management
Guinea-Bissau/Guinea	Mangrove/Ecosystem management
Guinea/Sierra Leone	Rural development, Agriculture
Sierra Leone/Liberia	Rural development, Mano River/Ecosystem management
Liberia/Cote d'Ivoire	Rural development, River/Ecosystem management
Cote d'Ivoire/Ghana	Lagoon/Ecosystem management, Tourism, Urban expansion, Fisheries
Ghana/Togo	Erosion, Freshwater, Urban expansion
Togo/Benin	Lagoon/Ecosystem management, Freshwater, Erosion, Urban expansion
Benin/Nigeria	Lagoon/Ecosystem management, Freshwater, Erosion, Urban expansion
Nigeria/Cameroon	Cross River-Korup Ecosystem Management, Petroleum development, Fisheries

5.2 OPPORTUNITIES AND CHALLENGES FOR REGIONAL COASTAL CLIMATE CHANGE ACTIVITIES

West Africa presents both significant opportunities and barriers to transboundary and regional coastal management and sharing of lessons, many of which are related to historical experiences. Opportunities relate to the small size and shared ecosystems of most West African countries, varying levels of economic integration in the region, as well as a generally positive, albeit challenging, history in the development of regional environment activities, such as the Permanent Interstate Committee for Drought Control in the Sahel (CILSS), the Abidjan Convention, and Large Marine Ecosystems. Yet the barriers are also significant, particularly relating to limited research and technical capacity, challenges of integration of coastal planning processes, the language barrier between Anglophone and Francophone countries, rapid coastal urban growth, emergence from decades of conflict, and a lack of history on engaging in climate change and climate impacts.

Given the relatively **small size and low populations** of many West African countries (only Cameroon, Nigeria, Ghana, Côte d'Ivoire, and Senegal have populations of more than 10 million), there is an inherent benefit in sharing at a regional level, particularly given the diversity of issues affecting coastal systems. Benefits could emerge from centers of excellence that provide regional support, and while this has been attempted to some extent through the Abidjan Convention, at present there is not a leading regional institution working on climate change considerations.

Most West African countries have **shared ecosystems** with neighboring countries, offering potential for shared services or collaboration similar to CILSS, though, as noted above, this has not been realized at the coastal zone. From a bilateral perspective, waterways represent national boundaries, as in the cases of Nigeria-Cameroon, Benin-Togo, Ghana-Côte d'Ivoire, Côte d'Ivoire-Liberia, Liberia-Sierra Leone, and Senegal-the Gambia. In these cases, management of deltas becomes an important area of collaboration, particularly on navigable waterways. In these deltas, collaboration on mangrove management is an important concern. In addition, there are existing, bilateral ecosystem management processes and discussions in many of these neighboring countries. USAID's support for transboundary ecosystem management through the Sustainable and Thriving Environment for West African Regional Development project has opportunities to extend its work in the coastal zone. The Canary Current Large Marine Ecosystem (CCLME) — encompassing Senegal, the Gambia, and Cape Verde—and the GCLME — affecting the coast from Guinea-Bissau to Angola — each provide multi-country regional ecosystems to coordinate on fisheries and coastal management. Indeed, these ecosystems have been the geographic basis for the long-term Global Environment Facility-funded projects of the GCLME and CCLME.

West Africa still requires significant efforts to achieve economic integration; however, the increased **coordination on economic issues** bodes well for collaboration. The role of ECOWAS through the forthcoming West African Monetary Zone, and the West African Economic and Monetary Union's (UEMOA) success in harmonizing the West African Franc create political momentum for coastal coordination and collaboration.

Despite the opportunities, clear barriers remain. The ECOWAS Climate Change Regional Program Action on Climate Change Vulnerability identifies three main constraints at the regional level: low organizational capacity; a fragmentary approach among countries; and the challenge of integrating adaptation into vulnerable sectors. As a result of relatively small populations in each West African country and a history of conflict, there is **limited technical capacity** in any given country. A 2005 New Partnership for Africa's Development (NEPAD) study on climate change identified 1380 African scientists involved in global change research (including, but not limited to, coastal climate impacts), of which less than 20 percent are of West African origin, and more than 50 percent of these West African scientists are from just two countries: Nigeria or Ghana (NEPAD, 2005). While these numbers are certainly growing, in part due to dedicated programs such as West African Science Service Center on Climate Change and Adapted Land Use (WASCAL) and the increasing prominence of climate change as an issue, it is illustrative of: 1) the limited capacity pool to draw from; and 2) the distinct need to share human scientific capacity across countries (Table 16). While much of the analysis associated with climate change research can be done by consultants and international experts, there is a distinct need to collect and assess data in-country. Indeed, the absence of continuous 30+ year temperature and precipitation data across much of Africa has limited the ability to undertake downscaled climate analyses, thus limiting the ability to engage in climate resilient planning at a national level.

TABLE 16. NUMBER OF AFRICAN SCIENTISTS INVOLVED IN GLOBAL CHANGE RESEARCH

Country	Number of Scientists
Cape Verde	0
Gambia	1
Guinea	2
Guinea-Bissau	2
Liberia	2
Cameroon	3
Benin	12
Senegal	20
Sierra Leone	21
Togo	26
Côte d'Ivoire	41
Nigeria	51
Ghana	71

Source: NEPAD, 2005

This situation would seem to encourage collaboration and the development and use of regional think tanks; however, there is limited evidence of regional collaboration with respect to information generation and analysis. Academic and research institutions with broad research capacity are primarily located in Senegal (at the *Centre de Suivi Ecologique*), Ghana, and Nigeria; however, there are regional experts with important research labs in Guinea, Côte d'Ivoire, Benin, and Cameroon. Additionally, regional West African data comes from non-coastal countries through the African Center of Meteorological Application for Development (ACMAD) in Niamey, Niger. The experience of CILSS in promoting information consolidation provides hope for regional information and analysis hubs on coastal issues. However, to date, much of the coastal information generated within countries remains only available in country and only if paid for. Even as regional centers of excellence are created, the pool of applicants is extremely limited. This is evidenced by ACMAD's multi-year search for West African individuals with specific climate-modeling expertise. To the extent that these capacities exist within West African individuals, these individuals are in high demand globally, particularly in Europe and North America, where such researchers can obtain international salaries.

Language is one of the most significant barriers to transboundary collaboration on coastal management. Scientific and intergovernmental sharing of lessons remains possible, though typically it is uni-directional, primarily because Francophone academics and intergovernmental professionals often have strong English skills. Thus while lessons from Anglophone countries may reach Francophone countries, the French academic and gray literature has a much more limited opportunity to reach Anglophone countries, as French skills in Anglophone West African countries are extremely rare. This is unfortunate, as Francophone research organizations such as the *Institut de Recherche pour le Développement* (Institute of Research for Development) have a strong research history in coastal West Africa, as well as long-term collaboration with national research organizations. Particularly on the part of Anglophone donors, there is a need to explicitly invest in exploring the deep Francophone literature of the region.

Rapid urban growth coupled with **limited integrated coastal planning** present significant obstacles to integration of climate change resilience into West African development processes. Ad hoc decisions with respect to new informal settlements can result in institutionalizing long-term vulnerabilities to climate variability and change. Informal settlements often emerge in marginally habitable areas, such as flood plains, dunes, and steep slopes on the fringes of cities. A lack of planning processes often results in these areas becoming progressively formalized. These areas are particularly vulnerable to extreme weather and long-term climate impacts. An extreme example is the Makoko slum of Lagos, which has evolved over the past 40 years into a community of more than 85,000 inhabitants (Figure 25). Once established, these communities gain a form of de-facto tenure rights and it becomes increasingly challenging to engage in formal planning, particularly as it might relate to retreat and relocation. While the challenges of service delivery (health, education, and water) are perhaps more pressing development challenges, increasing resilience to climate change and engaging in forward thinking land-use planning is a critical challenge.

FIGURE 25. THE URBAN SLUM OF MAKOKO, A COMMUNITY BUILT IN THE HIGHLY VULNERABLE LAGOON OF LAGOS.

Source: Jon Gambrell/AP

The **history of conflict** over the past two decades through civil war in Sierra Leone, Liberia, Guinea-Bissau, and Ivory Coast, *coups d'etat* in Gambia and Guinea, and ethnic conflicts in Benin and Nigeria have created a particular challenge for addressing issues such as climate change within countries, let alone opportunities for transboundary collaboration. Conflict and its aftermath reduce opportunities for the long-term planning processes associated with climate change. Delivery of basic services, rebuilding infrastructure, and maintenance of stability become the primary functions of government following conflict. In principle, this rebuilding in a post-conflict environment could provide an excellent entry point for integrating climate change resilience into planning; in practice, however, there has been little evidence of appetite for consideration of climate change in these humanitarian emergency, post-conflict environments.

In addition to the toll that conflict takes on infrastructure and stability, scientific research and monitoring systems are almost always abandoned during these times, often resulting in decades-long gaps in climate and biophysical records. This can be observed in the weather datasets for each of the above countries. Universities and research institute studies often grind to a halt and academic faculty are among the first groups to leave during conflict and the last to return. While in some cases research can begin anew following conflict, the resultant gaps in long-term datasets can have significant repercussions on the ability to downscale climate information.

The **"new" climate change lens** provides both opportunities and barriers for collaboration. On one hand, climate change adaptation in the medium-term has generated a great deal of funding opportunities and will continue to be a buzzword as donors increasingly adapt their development narratives to align with climate change challenges. It varies as to whether this represents new and additional financing, as called for under the UNFCCC, as many existing priorities are retrofitted to meet climate change adaptation earmarks. In almost every sector, the implementation lags behind the science and policy. In many cases, standard development practices are being applied to address traditional development challenges, and the climate change terminology is simply used as a justification for standard development. This can be seen in many of the proposals developed for the National Adaptation Programs of Action under the UNFCCC. This lack of a change in practice may be reflective of a lack of adequate information to make decisions, a lack of training at the implementation level, and/or a lack of information on effective adaptation interventions. Clear efforts are required at the research level to better elaborate the relationship between climate change and coastal-development challenges, and to develop, trial, and test adaptation options. There is a distinct need to deliver capacity-building efforts to those implementing traditional development activities, so that they understand the relevance of climate change.

This climate change lens also presents risks, as it may move focus away from non-climate stressors and standard coastal development challenges. For instance, if coastal challenges and responses are framed primarily under a climate change lens, actors seeking to improve coastal management may fail to identify threats posed by the development of coastal infrastructure, or over extraction of freshwater by growing urban populations.

5.3 INSTITUTIONAL ANALYSIS FRAMEWORK

The development and implementation of adaptation solutions at the national and regional levels requires a collection of functions, typically housed under multiple institutions. Equally important are mechanisms for these institutions to interact to ensure that these functions are part of an iterative process. Core functions for effective adaptation that lead to results at scale include:

- Collection and assessment of information to guide decision making;
- Prioritization of issues to identify entry points for engagement;
- Development of policy and coordination of options;
- Implementation of policy and practice; and
- Information management to learn from the process, adapt practice, and share lessons.

The connection between identifying a problem, collecting information on the problem and solutions, developing and coordinating policy, implementing and enforcing policy, and revising and sharing lessons requires specific capacities at each of these stages, as well as strong mechanisms for coordination as transition are made between the stages. Within this framework there are significant human capacity needs; a recognition of the need for a transparent and participatory approach that welcomes all stakeholders; and flexible institutional roles and responsibilities.

5.3.1 Assessment

The assessment phase of adaptive capacity brings in climate and social science for decision-making around key adaptation questions. Assessments frame available information around vulnerability of prioritized sectors and link climate change information to non-climate sectoral stressors and development outcomes. Assessments may require new information, but initially should help to clarify causal chains by identifying the relative role of climate change within sectors. Despite the valid call for more data around climate change impacts and coastal processes, there is historically a poor connect in West Africa (and across much of the globe) between good scientific information and the development of policy. Much of the information that is generated with respect to climate change impacts and coastal processes is not necessarily policy relevant. For example, knowledge of the impacts of ocean temperatures on fish populations, or the expected extent of sea-level rise at a regional level, does not necessarily provide decision makers with clear actions. There is a need for coastal management questions to be asked in a form that can generate actionable and informed responses. All too often, assessments are undertaken and their results ignored or forgotten when decisions are made, highlighting the central role of a mechanism to link consolidated, decision-relevant information to decision-making processes.

The institutions most often leading this assessment work are research- and knowledge-generating organizations. They may be contracted to perform specific analysis, they may be brought to the table to provide in-house data, or, ideally, they may lead the development of decision-relevant framing questions and consolidation of information. Institutions in coastal West Africa tend to contribute to assessments through specific short-term consultancies, or as providers of primary data. Academic institutions are often not the most appropriate institutions to lead this process, as it is less focused on generating new knowledge and more focused on connecting dots around existing knowledge to develop and answer policy relevant issues. These roles are increasingly filled by organizations known as "boundary organizations," typically think tanks that bridge the boundary between science and policy. As noted above, West Africa is currently lacking in environmental and coastal-issue think tanks with the breadth and depth to explore

An even more vexing challenge at present is the lack of freely available data. Historical data on climate and coastal processes is absent and cannot be recreated in many post-conflict countries, posing challenges to developing future projections (which are partially based on validating models by using historical data). In a number of other cases, the national institutions that house data (for example, oceanographic or climate data) will only make data available at a significant price. Even if data is available, different methods undertaken in different countries pose challenges to developing regionally or even nationally comparable analyses.

At present, there are no national or research institutions in West Africa taking a leading role in developing coastal climate change assessments and leading systematic cross-sectoral reviews. A number of individual researchers are leading work on specific scientific questions in the region (for example, related to coastal erosion, fisheries, or coastal livelihoods). Some of these individuals could lead multi-disciplinary teams from within their institutions to characterize and assess vulnerability, but this research-focused model is not as strong as an institutional model, due to the competing demands that most academics face. The relative lack of coastal- or climate-change-focused think tanks in West Africa is a weakness, and this void is likely to continue to be filled by individual researchers, a select few regional universities, and international consultants and organizations.

5.3.2 Prioritization

The function of prioritization requires decision makers, knowledge generators, and broader public stakeholders to use the information generated within assessments to understand the problem(s), and prioritize challenges and appropriate solutions. This action is neither purely scientific nor political, and as a result it requires an iterative process of consultation. Few governments in any country are able to make decisions primarily on the basis of well-informed science, or through participatory processes. Yet, for climate-adaptation decisions to be effective, they must be based heavily on science and projections that are decades into the future. The National Adaptation Programs of Action carried out under the UNFCCC used a multi-criteria analysis approach to prioritize adaptation options, and, while flawed, they at least incorporated a transparent process of prioritization.

Regional priorities strictly around coastal protection are likely to focus on rehabilitation and construction of coastal infrastructure, re-evaluation of mangrove fishing practices, protection of estuaries for spawning grounds, improvement of coastal-erosion monitoring, construction of flooding infrastructure, and improved land-use planning in coastal towns. Specific activities will address freshwater management and protection of reservoir sites, and greater understanding of surface and groundwater dynamics around urban areas. Fisheries activities are likely to address modernization of artisanal fishing, expansion of aquaculture, regulation of fishing practices, and formulation of national fishing policies. In working at the regional level, it is important that local context-specific opportunities and issues are not ignored.

5.3.3 Policy Development and Coordination

Once problems and solutions are understood and solutions are developed, the creation of incentives at the national level is a distinct challenge. This process is most often led by policy- and decision-makers who may have varying degrees of strengths and familiarity with the range of issues within coastal management. There are at least three levels of coordination implied in this work: across sectors (horizontal); across national, regional, and international groups (vertical); and across stakeholder groups within sectors (intersectoral).

In the search for climate-smart solutions to climate impacts in the coastal zone, practitioners are required to think across disciplines and ecosystems. Yet it is impractical for individuals to be experts across the coastal intersection of industry, transportation, environment, tourism, rural and urban livelihoods, and the full range of coastal interests.

Vertical coordination has a collection of processes and mechanisms through ECOWAS, the Abidjan Convention, and the Interim Guinea Current Commission (IGCC), but these levers are relatively weak and there are few enforcement mechanisms related to climate-change resilience. Logistics present a real challenge to regional collaboration, as technical and policy meetings are only likely to bring together one to three individuals from each of the 14 West African countries. Due to the diverse number of sectors at the coast, there is a challenge in matching the necessary technical and political depth and breadth at any given coordination meeting. The GCLME Interim Guinea Current Commission has sought to resolve this challenge by focusing its efforts on environment ministers and suggesting approaches for intersectoral coordination within individual governments.

Intersectoral coordination between civil society, the private sector, and government on coastal management has seen success around individual projects addressing discrete coastal challenges, such as infrastructure development or erosion control measures. However, at a larger planning scale, examples are fewer. In countries such as Liberia, there is almost no civil society or private sector to engage with on coastal issues and, in most countries, enforcement of laws and regulations related to coastal resources is weak.

5.3.4 Implementation

Implementation capacity is perhaps the most challenging element of this framework to operationalize. The other elements of this framework can largely be met by building institutional and human capacities of a relatively small group of individuals within any given country. However, the integration and implementation of adaptation activities at scale requires: massive financial resources; capacity and training of public- and private-sector implementers; large-scale public engagement; and political will to implement regulations that alter economic livelihoods. It is unclear at present whether West African countries have the political will to mobilize this type of response for coastal adaptation.

Despite the challenges outlined above, a surprising number of coastal and climate-change processes, strategies, and plans have been developed over the past decade across West Africa, as well as numerous project proposals. Depending on the policy or program, implementation may be led by government, the private sector, international organizations, or local actors. Tracking implementation is a challenge, and the relationship between policy and implementation is limited by capacity gaps and insufficient funding.

This institutional assessment largely avoids the issues of local implementation of policy by institutions and independent adaptation by local populations. Nevertheless, in most cases, local implementation of policy is limited by the low technical capacity and limited resources at the disposal of extension agents and public servants. Many of the most pressing adaptation challenges are less about hard/infrastructure-based solutions, and more related to resilient-planning and adaptive management. These approaches are less likely to rely on one-size-fits-all/prescriptive solutions, but rather require facilitation and scenario building. This approach to implementation requires a specialized, but not strictly technical, skill set. This lack of a definitive solution and challenge in defining the problem means that extension agents, in many cases, will need to be trained in a new approach to their work.

At a regional level, the International Institute for Sustainable Development (IISD) has identified particular gaps in regional West African programming related to freshwater supply, forestry, and pastoralism, though a number of national programs focus on freshwater. IISD notes that most regional projects support research capacity-building and knowledge communication, but that consideration of gender issues is largely unaddressed (IISD, 2011).

5.3.5 Information Management

Information management is central to learning and adapting. There is a role of government and implementers to collect information on activities, evaluate success, and share results broadly. Ideally, this will feed back into the prioritization process and national planning. All too often, however, the lessons learned are processed by the international implementing entity and the lessons do not make their way into national practice. At the regional level, databases and forums for learning and sharing can play important roles. Often, databases are not maintained, process forums slowly fade from view, and learning does not make its way into an adaptive management cycle. West Africa does not have a regional coastal database that is easily accessible, though some institutions have regional information on climate and oceanographic variables collected at the regional level.

Dynamic adaptation communities of practice have emerged across Africa; however, these have primarily been in the areas of agriculture and freshwater management. There is a need for more active communities of practice on climate change and coastal management.

5.4 INSTITUTIONS

5.4.1 Funding Institutions

The primarily funders in the region for coastal-zone adaptation have been the Global Environment Facility (GEF), Food and Agriculture Organization of the UN (FAO), United Kingdom, France, Canada, Denmark, Germany, and the U.S. The Least Developed Countries Fund (LDCF) and Adaptation Fund have played important roles in funding activities. Various international groups, such as Wetlands International and the International Union for Conservation of Nature (IUCN), have been conduits for funding and implementation. There is limited evidence of private-sector interest/engagement in funding climate change adaptation activities. However, large international businesses active in the region (for example, in oil, mining, and infrastructure development) undoubtedly have some consideration of coastal risk management in their planning operations. As climate change impacts become more evident, there will undoubtedly be a greater integration of climate change into planning of water services and coastal infrastructure development.

5.4.2 Regional and Continental Institutions

West Africa is home to a collection of intergovernmental organizations, which have been established based on ecosystem boundaries (GCLME, CCLME), historical language and monetary relationships (UEMOA), regional trade liberalization (ECOWAS), and specific environmental challenges that expand beyond the region alone (Abidjan Convention). These institutions will act as important hubs for future regional coordination and collaboration on coastal management. Their strengths (to differing degrees) lie in the potential to create dialogues for issue prioritization, policy coordination, and common action. Each has high capacity in its leadership; however, each has limited human resources to dedicate to research, capacity building, implementation, and sharing lessons at a regional level. The generation of information and analysis must be performed by additional institutions, as must the implementation of activities and the development and distribution of lessons learned. Based on the reviews undertaken in this work, there are no clear organizations that operate at a regional level to lead on research, implementation, and sharing of lessons. There are some national institutions and continental or global institutions that have the ability to reach beyond national borders in the region (and have some history in doing so), and these organizations should be supported to reach beyond their existing comfort zones.

The **Abidjan Convention** is a logical institution to be engaged in coordinating coastal policy and information across West Africa. Its mandate is broad, encompassing cooperation in the protection and development of marine and coastal environments in West and Central Africa, including a protocol on the control of pollution. With the support of UNEP and in coordination with the GCLME, each member of the convention developed a National State of the Coast Report.[4] UNEP provides the secretariat function for the convention within the regional coordinating unit located in Côte d'Ivoire. While the secretariat is a small unit, its biennial Conference of the Parties, as well as support for a range of regional meetings, provides a forum to be a leader in policy coordination and coherence. It therefore has the potential to help integrate climate change into the range of coastal processes.

The convention came into force in 1984 and focused on pollution control, coastal erosion, environmental legislation, and impact assessments. By the early 1990s, the convention was almost inactive until 2002. The development of the Large Marine Ecosystem (LME) projects in the Benguela, Guinea, and Canary currents acted as sub-regional hubs for implementation of the convention. To date, the LMEs retain a central role in the implementation of the convention and in guiding its scientific agenda. The convention has increasingly taken climate change as a relevant issue to consider, but within the organization there is no single climate change focal point. The convention's relevant role in responding to climate change is related to policy and coordination among countries, as it has a very strong link to national environment ministers and coastal stakeholders. To this end, the convention is well-poised to facilitate and coordinate regional decision making.

From a geographic perspective, the 15 countries of **ECOWAS** match closely with the West African coastal countries considered in this assessment (with the exceptions of Cape Verde and Cameroon). ECOWAS was founded in 1975 to promote economic integration across all areas of economic activity, and it has played a central role in pursuing a unified West African currency. The political and economic importance of ECOWAS within West Africa makes ECOWAS a particularly strong partner in ensuring that climate change is on the regional agenda and considered within activities of the ECOWAS Commission. ECOWAS has a strong political mandate to coordinate regional policies through its

---

4 Please visit this website to view the full report: abidjanconvention.org/index.php?option=com_content&view=article&id=106&Itemid=206

environment directorate. In this aspect, it has a role in convening countries to share experiences, making available best practices and providing legal governance advice.

The mandate to work on climate change emerged from the 2007 ECOWAS Ministerial Dialogue on Climate Change and the subsequent development of a plan of action that aims to: support adaptation processes at the policy, technical, and financial levels; harmonize and coordinate national adaptation initiatives; and mainstream climate change in regional investments.

A particular challenge facing ECOWAS in mainstreaming climate change into its activities, including coastal zone work, is that climate change is one element of the agriculture, environment, and water resources department. This siloing of climate change concerns into environment departments is common within international and national organizational structure, but can create barriers when trying to integrate climate work into other areas of the organization, such as the infrastructure department of ECOWAS. Across almost all West African countries, the ministries of environment have been given charge over climate change issues, as well as coastal issues related to the Abidjan Convention. This presents positive prospects for internal coordination. The primary cause for concern in each of these countries, however, is the role of the environment ministry vis-à-vis other ministries and sectors, particularly when coastal issues touch on urban growth, maritime transport, mining, and fisheries. The limited power of environment ministries threatens opportunities to mainstream climate change into coastal-management practices. The LME process has attempted to avoid this ministerial silo.

ECOWAS has a complementary role to the Abidjan Convention with respect to climate change considerations. While both institutions have their primary role in policy and coordination, ECOWAS is better equipped to work on policy harmonization, as this is a primary element of the ECOWAS mandate. Furthermore, ECOWAS is likely to have a stronger linkage to implementation than the Abidjan Convention, as it plays a role in the facilitation of regional and transboundary projects. Like the convention, ECOWAS does not have a large staff focused on climate-change considerations and, as a result, for ECOWAS to fulfill its harmonization objectives related to climate change coastal considerations, there is a great deal of technical assistance that is necessary.

The role of the **West African Economic and Monetary Union (UEMOA)** — established in 1994 and based in Ouagadougou, Burkina Faso — is primarily to build economic and trade integration across Francophone West African countries, including Benin, Togo, Côte d'Ivoire, Guinea-Bissau, and Senegal. This limits the capacity of UEMOA to work across the whole region. To some extent, UEMOA presents a parallel system to ECOWAS and this has the potential to create challenges between the two organizations. Outside of its monetary coordination role over the *Communauté Financière Africaine* (CFA), UEMOA does not have a large regional political coordination role. UEMOA's strongest link to coastal and climate-change issues is related to its Regional Shoreline Monitoring studies with the IUCN in 2010 within its Regional Program to Combat Coastal Erosion (one of UEMOA's eight sub-programs on environment). UEMOA brings a powerful perspective to coastal management work, a focus on the implications of urban growth and economic infrastructure development. As a result, UEMOA's approach to developing coastal zone management plans that are explicitly preparing for a much more populated and increasingly urbanized West African coast is welcome. To date, UEMOA's work has been primarily technical in nature, while allowing ECOWAS to engage in the policy elements of climate change interventions. UEMOA has played, and will likely continue to play, a niche role in coastal issues and in the response to climate change. Its leadership on coastal erosion will likely continue through the development of a regional monitoring institution. It remains to be seen whether UEMOA will expand its efforts beyond coastal erosion as it carries out its environment mandate.

The development of an ***Observatoire du Littoral Ouest Africain* (West African Coastal Observatory, OLOA)** as a program of UEMOA was envisioned based on the UEMOA-commissioned work on coastal erosion. This coastal-monitoring institution was launched in April 2013 and will be hosted by the Government of Senegal. It will contribute to regional coordination on coastal erosion and management through data collection, and bring information to coastal actors with the goal of developing a common vision around management of coastal erosion. The ability of this institution to achieve integration beyond the five coastal members of UEMOA is unclear. The consideration of the role of climate change in OLOA will be an important issue to consider as the organization matures.

The Large Marine Ecosystem "projects" in the Guinea Current and Canary Current, heavily supported by the U.S. National Oceanographic and Atmospheric Administration (NOAA), have been long-term research and investment programs that have leveraged significant funds for coastal management. These projects have linked scientific research to regional collaboration on IUU fishing and pollution control, and provide excellent opportunities for increasing the role of climate-change considerations within existing coastal research. The two regional programs have leveraged four times their GEF funding during their last five-year program phase. The main limitation of the LMEs is that they have been heavily reliant on GEF funding, with a slowdown in activities over the past year in the Guinea Current during a funding gap. Activities during the next funding cycle are to increasingly move management and control to the participating countries. It remains to be seen how this transition will be undertaken and whether continued international support for the LMEs will be provided.

The **Guinea Current Large Marine Ecosystem (GCLME) project** has been funded by the GEF and UNDP since the early 1990s. The GCLME has a mandate to coordinate regionally, working with the 16 Guinea Current countries and, specifically, with the member countries of the Abidjan Convention. This platform includes all countries of West Africa except Senegal and the Gambia, and has significant opportunities to coordinate climate-change work and knowledge regionally. In particular, the successive projects from the early 1990s created a network for regional marine data and information acquisition and exchange, and regional capacity for resource management had great potential. But for various staffing and structural reasons, the project has not lived up to its full potential thus far. Over the past two decades, regional centers of excellence have been established to support the implementation of strategic action programs and national action plans by the IGCC member states. However, these institutes, almost without exception, have acted as service providers in response to specific requests, as opposed to drivers or champions of change. This reflects a concern that should be considered in the development of regional centers of excellence around climate change. With the end of the GEF-sponsored program in 2012, there has been a gap in implementation of the GCLME agenda.

Based on this work, the countries of the GCLME each have national action plans (completed in early 2011) and national programs of action for the protection of the marine environment from land-based activities, with associated coordination structures and inter-ministerial committees. However, the next phase of the GCLME work is anticipated to begin as of the drafting of this document, and is likely to result in the revitalization of the Guinea Current Commission, with significant support of NOAA.

The **Interim Guinea Current Commission (IGCC)** emerged from the GCLME project. The ICGG first met in 2006 and functioned as a steering body and coordination unit that guided the use of national action plans for each GCLME country[5] and a regional strategic action program (SAP) (IGCC, 2008). The SAP outlines a collection of broad ways in which climate change could impact the management of the GCLME, but underscored that the "inability to predict events and changes limits the capacity to manage effectively system-wide." The SAP further suggests that a parallel project to address climate impacts on the coastal zone would be developed under the GCLME, though there is no evidence that this has come

[5] Please visit this website for more information: www.gclme.org/index.php?option=com_content&view=article&id=7&Itemid=8

into being. The lack of specificity in the SAP on the links between climate change and the goals and actions of the GCLME is a major weakness in effectively integrating climate into coastal-management issues in West Africa. This is further substantiated by the fact that country investment project profiles in each GCLME country have resulted in 43 national project ideas, only three of which mentioned climate change and none of which mentioned climate change as a primary driver/justification (IGCC, 2010). On the whole, it is not clear whether these prioritization processes that fail to fully integrate climate change represent the relatively small role of climate change in dealing with urgent development and coastal resource-management challenge, or whether it simply reflects a lack of understanding on the interactions between climate change and each coastal issue.

In 2010, the GCLME environment ministers agreed to create a permanent Guinea Current Commission (GCC) — based in Accra, Ghana — composed of ministers from member countries. However, since the completion of the GCLME in 2012, little has been heard from the GCC and its prospects for achieving the goal of a country-owned, independent, and permanent commission for the management of marine and coastal resources are uncertain.

The **Canary Current Land Marine Ecosystem (CCLME) project** specifically includes a component on regional collaboration, and has developed an incipient climate-change working group. With respect to fisheries and conservation of nurseries and reproductive habitat, the CCLME provides an excellent institutional framework for integration of climate change. While the climate-change working group was established in May 2011, there is little evidence for subsequent dedicated climate work. The framework for a transboundary diagnostic analysis and strategic action program under the CCLME provides a promising approach to develop capacity and identify and implement reforms.

The GCLME and the CCLME fill crucial roles in linking the policy and coordination undertaken under ECOWAS and the Abidjan Convention with international scientific and research roles called for to assess the impacts of climate change and other coastal threats, and to understand the impacts of project implementation. Because the LMEs have the collection of scientific information about coastal systems at their core, and they are funded largely by international actors and researchers, there is the potential to generate a great deal of information and to leverage significant research resources. Thus far, the LMEs have done an enviable job at promoting assessments of national states of coastal resources, and threats, and they have attempted to develop centers of excellence. The LMEs have also seemingly caught the attention of national ministers and political interests. Despite these achievements, which should be built on in the coming years for the purpose of climate change adaptation, there has been relatively little experience in local implementation generated through these projects for coastal adaptation. Furthermore, the large limitation that has faced the LME projects is their project focus. Because of a gap in funds since mid-2012, the LMEs have been relatively inactive. However, the LMEs' strong link to international research institutions and intergovernmental organizations provides significant opportunities for linking their activities to cutting-edge science and building research institutions' capacities. By using this mechanism to develop a regional research think tank around climate change and regional coastal issues, the LMEs could spur new innovation.

The **Regional Charter and Action Plan for Sustainable Mangrove Management** under the IUCN and Wetlands International brought together the Gambia, Guinea, Guinea-Bissau, Mauritania, Senegal, and Sierra Leone to promote harmonization of national policies on mangrove management in 2010. The development of national action plans within this regional charter provides a baseline for tracking progress on mangrove management (IUCN, 2010). The expansion of this charter may be a useful mechanism to build momentum around regional mangrove management and integration. Wetlands International and the IUCN continue to support the implementation of this action plan, though the specific achievements since 2010 are unclear. As a result, coastal climate-change work on mangroves must consider this regional charter, but there is relatively little to collaborate on, as there is no central institutional home. The success of the initiative is reliant on goodwill and in-country capacity/interest in carrying out activities. Climate-change work related to mangroves should call upon the IUCN and Wetlands International for technical support, but the work is not necessarily integrated into a broader climate change and mangroves initiative locally. In contrast, the global U.S. Forest Service- and USAID-supported Sustainable Wetlands Adaptation and Mitigation Program, implemented by the Center for International Forestry Research and University of Oregon, provides potentially useful support for regional collaboration on mangroves.

The **AGRHYMET Regional Center** was created in 1974 as a specialized institute of CILSS with the goals of contributing to food security, improving natural-resource management, providing training in agroecology, and applying science and innovative techniques to rural development. It has become a regional center for training scientists and leaders in agricultural science and extension. While it is a beacon of success in the areas of food security, its mandate does not extend to coastal zones. Nevertheless, the example of AGRHYMET in developing a comprehensive donor-base and range of services that it can provide across West Africa is a model to examine in the support of coastal institutions. The coastal zone may require its own AGRHYMET organization that can consolidate regional information on marine and coastal resources and link this work to broader socioeconomic and biophysical conditions.

The **African Monsoon Multidisciplinary Analysis (AMMA)** program has been operational since 2002 and the current phase runs through 2020. It is based with AGRHYMET Regional Center, with the goal of studying the West African monsoons and projected changes over the 21st century and how these changes will impact health, water resources, food security, and demography. It provides access to monsoon data for researchers (amma.agrhymet.ne). AMMA's approach integrates a human perspective to its climate models. Despite its regional focus, its scientific steering committee of 15 individuals has representatives from only five West African countries (Nigeria, Senegal, Ghana, Côte d'Ivoire, and Niger). AMMA's training program engages with a dozen West African universities. Like much of the climate research in West Africa, AMMA focuses on rural dry areas, as opposed to the coast, though it does have a research program on impacts on coastal mega-cities. The coastal mega-cities research is of broader interest to the West Africa assessment and should be followed closely. While at present this work is largely based on modeling climate impacts, there will be great value in considering socioeconomic pathways and transition, particularly related to coastal mega-cities, as the work develops through 2020. The relationship between AMMA and regional universities is an important approach that should be followed in future information-generation activities. A similar type of program, the **West African Science Service Center on Climate Change and Adapted Land Use (WASCAL)**, seeks to build West African research capacity through doctoral and masters programs and research in 10 West African countries including Benin, Côte d'Ivoire, the Gambia, Ghana, Nigeria, Senegal, and Togo. While coastal issues are not explicitly included in the WASCAL program, future iterations of the program should examine opportunities to scale out solutions to address climate change issues on coastal zones.

BOX 2

Coastal West African universities collaborating with AMMA:

- Agence Universitaire de la Francophonie (Côte d'Ivoire);
- Université d'Abidjan Cocody;
- Université de Yaoundé;
- Université de Cheik Anta Diop de Dakar;
- Université d'Abomey-Calavi
- Université d'Ibadan; and
- Ecole Superieure Polytechnique de Dakar

5.4.3 Continental and Global Institutions

There are few continental institutions and projects working on coastal challenges, while globally there a large number of institutions collecting information on oceans and coastal areas. Their applications to regional challenges vary; however, for the most part, they are scientific institutions generating information that may be applicable to West African coastal considerations.

The **African Center of Meteorological Application for Development (ACMAD)** has been in operation since 1987 with the goal of providing weather and climate services across Africa by engaging in weather prediction, climate monitoring, technology transfer, research, and capacity building of the National Meteorological Services. ACMAD produces short-term and seasonal forecasts, as well as longer-term climate projections. It acts as Africa's regional climate center, and manages the ClimDev Serv program, which strives to help make climate-related information available to end-users. To date, these services have been almost exclusively targeted toward agricultural systems, and the information services have not been linked to coastal or marine processes. ACMAD is among the strongest African institutions on climate modeling and climate services, but it has been challenged to find qualified candidates to fill positions. As a result of these functions, ACMAD has a strong potential role to play in understanding the dynamics of coastal changes; however, it would require a revision of their standard role, and the development of relationships with marine-research institutes. Climate impacts in the coastal zone are mediated through the sea and global currents. As a result, while severe weather and changes in precipitation and temperature will have important coastal impacts, the scale of the impact is often directly related to tidal fluctuations, storm surges, and seasonal ocean temperatures. Should ACMAD wish to engage coastal users of climate information, it will likely need to build specific new capacities. ACMAD is unlikely to engage in policy, coordination, or prioritization of coastal climate-change issues, but it will provide crucial inputs to these processes.

The African Monitoring of Environment for Sustainable Development (AMESD) program operated from 2007 to 2013 to improve environmental monitoring across Africa. It had regional nodes based out of regional organizations, including an ECOWAS node based out of AGRHYMET, focusing on water management for cropland and rangeland management. Marine and coastal management was one of its five priority areas; however, this was managed for the Indian Ocean Commission (IOC) from the Mauritius Oceanographic Institute, and the observation services developed around fish resources monitoring and physical oceanography were not made relevant to the West African context. While the AMESD program could not be expected to cover every issue in each region of Africa, it serves to illustrate the narrative of West African information needs focusing on dryland management, and not coastal issues. The lessons from the IOC are likely transferable to West Africa. This underscores the importance of broad outreach for continental and global programs to have impacts at scale.

The **New Partnership for Africa's Development (NEPAD)**, a strategic framework for the African Union, has a mandate to work on rural development, agriculture, and climate-change activities including coastal management through its environment program. The Partnership for African Fisheries will promote a "think-tank" approach to encourage new solutions, focusing on key policy areas related to governance, illegal fishing, trade and access to markets, aquaculture, and finance and investment. To the extent that any adaptation investment link to food security, coordination with NEPAD's Comprehensive Africa Agriculture Development Program is worth pursuing. NEPAD's role in supporting the African Ministerial Conference on the Environment also provides an opportunity to bring coastal climate issues into a larger venue. NEPAD will not likely play a central role in West African coastal issues; however, successes in addressing coastal climate-change issues, particularly as they relate to enhancing food security, will be important to share with NEPAD.

The **Indian Ocean Commission Global Ocean Observing System (IOC-GOOS)** is a permanent system for observation and analysis of marine variables supported by the UN. It is the oceanographic component of the Global Earth Observing System of Systems. The observing systems include continuous plankton recorders, sea-level observation systems, floats that drift with ocean currents, hydrography samplers, censuses of marine life, and drifting buoys. The system also tests pilot projects to integrate into the global system. Relevant pilot projects include the marine impacts on lowland agriculture and coastal resources, and environmental statistic systems attached to ships of opportunity. It acts as a platform for international cooperation and the generation of oceanographic products and services, and has the potential to increase interaction between research, operational, and user communities. With the rise in global ocean temperatures and concerns over sea-level rise, GOOS has been at the forefront of the collection of oceanographic data and analyzing this data in the context of climate-change concerns. While there are a variety of organizations that house oceanographic data, GOOS and the **International Oceanographic Data and Information Exchange (IODE)** act as a clearing house for access to information and experts.

GOOS-Africa is a regional unit of GOOS active since 1998, including through the establishment of a network of African scientists. GOOS-Africa support to the GCLME projects has been through providing services for monitoring and predicting the dynamics of the LMEs and establishing early warning systems. The GOOS Regional Alliance is somewhat constrained in its relevance to West African coastal issues, as it covers the entire African coastline, and is therefore challenged to focus specifically on West Africa.

There have been intermittent attempts to develop a coastal-specific GOOS over the past two decades. The most recent efforts of GOOS to attempt this was the "Requirements for Global Implementation of the Strategic Plan for Coastal GOOS" (GOOS, 2012). The plan describes the building blocks of a coastal-observation system by outlining relevant coastal concerns and monitoring and modeling opportunities. It outlines coastal concerns related to loss of coastal bottom habitats, toxic algal events, human exposure to waterborne microbes, coastal eutrophication and hypoxia, coastal flooding, distribution of calcerous organisms, and fish-stock abundance.

To date, GOOS, GOOS-Africa, IODE, and the coastal elements of GOOS have not integrated into coastal decision-making in West Africa, and not all West African countries have been engaged in information exchange. Notably, Cape Verde, Guinea-Bissau, Liberia, Sierra Leone, and the Gambia have not collaborated on sharing data with the IODE network. The global information collected through these networks is relevant to coastal processes, and can provide consistent standards for coastal monitoring data. However, in addition to building the basic coastal- and marine-monitoring systems, to make this work relevant to climate-change impacts requires specific efforts to link the coastal-monitoring community to the climate-change community. While there is undoubtedly some overlap, this connection is not evident at present. One approach to linking these two communities is through the climate-services community. Those engaged in climate services and early-warning systems may be able to link information needs through discrete products and user needs.

The **African Marine Information System** is an EU-funded initiative to build open-source access to biophysical and water-quality assessments in coastal and marine waters of Africa. The information focuses on Earth-observation data, as opposed to observations from research stations. The data, which includes physical variables such as sea surface temperature and bio-optical variables that help to describe the surface productivity, is integrated in to the EU's Global Marine Information System. At present, this information system does not appear to add much value beyond the information available through IODE.

The **Group on Earth Observations (GEO)** includes a **Coastal Zone Community of Practice (CZCP)** and there is an emergent CZCP for West Africa that was the focus of discussion at the International Conference on Oceanography in Calabar, Nigeria, in November 2013, which focused on climate change and coastal areas sustainability in tropical and sub-tropical regions. This follows a 2010 workshop in Benin on decision-making support for coastal zone management, water resources, and climate change in Africa. The CZCP may act as a useful working group for linking data from GOOS to impacts of the marine environment on terrestrial coastal ecosystems. This link between terrestrial coastal processes and marine coastal processes is a discrete need for better understanding coastal dynamics and adaptation responses. Should a group develop out of this process, it may be able to help turn this community of practice into a group that helps to steer policy relevant questions.

The **World Meteorological Organization (WMO)** is one of the intergovernmental supporters of GOOS, and it leads the **Global Framework for Climate Services (GFCS).** The GFCS emerged from the 2009 World Climate Conference and is leading in the development of an implementation plan for linking observation, monitoring, and modeling of climate to climate-service information systems and user-interface platforms. To date, the GFCS has focused on four priority areas for delivering climate services, agriculture and food security, disaster risk reduction, health, and water. While the agriculture, disaster risk reduction, and water lenses have a great deal to offer for coastal environments, the specific foci of each of these priority areas have only somewhat addressed coastal zones. For example, the agriculture work has tried to address floods and drought in arid and semi-arid environments through seasonal climate forecasts and extension services. The disaster risk reduction agenda is developing multi-hazard early warning systems to consider climate-relevant hazards such as storm surges, severe rain, and cold and heat waves, alongside other threats such atmospheric pollution. In Cuba, this service is being developed to better predict the paths and impacts of hurricanes. Finally, the water priority area is developing flood-management tools to help communities and cities prepare for a variety of types of flooding. The GFCS is focusing its initial pilot activities on West Africa, but on the arid and semi-arid regions of Burkina Faso, Mali, Niger, and Chad. There is a distinct need to work on coastal tools and pilot them in both urban and rural areas. NOAA is a global leader on coastal climate services and its engagement in the GCLME could be strengthened to provide leadership on the development and piloting of coastal climate services.

The **Ocean Data and Information Network for Africa (ODINAFRICA)** is a program funded through UNESCO and Belgium to address coastal and marine data generation and use. Working in more than 40 institutions across 25 African countries, the program is active in Benin, Côte d'Ivoire, Ghana, Guinea, Nigeria, Senegal, and Togo. The program cuts across observation systems, data management, product development, and communication. It provides access to data on sea level, a marine atlas for participating countries. To date, it has not linked its services directly to climate change.

In addition to the above organizations, there are a collection of global programs that can provide access to coastal and marine data relevant to climate change decision-making in coastal environments. These include the **International Oceanographic Data and Information Exchange Program (IODE),** the **Food and Agriculture Organization's (FAO) fishery statistics,** the **Global Terrestrial Network for River Discharge**, the **Global Sea-Level Observing System**, the **Chlorophyll Globally Integrated Network**, **SeagrassNet,** and the **Natural Geography in Shore Areas**.

There are other capacity-building fora where West African institutions can participate. West Africa is underrepresented in the **Nippon Foundation Partnership for Observation of the Global Oceans**, and there are potential opportunities for developing a center-of-excellence training in West Africa to help strengthen the West African coastal- and marine-monitoring system.

Other regional and global collaboration opportunities are developing, for example through the emergent **World Association of Marine Stations (WAMS).** West African marine-research institutes and stations would likely benefit significantly from collaboration with a global network of institutes, and opportunities over the coming year are seeking to identify research gaps and potential partner organizations. Additional continental research institutes include the **African Institute of Mathematical Sciences**, which includes programs such as the Next Einstein Initiative supporting regional post-graduate opportunities and spanning various disciplines that include climate-change modeling.

TABLE 17. A SUBJECTIVE CONSIDERATION OF THE CAPACITIES OF A RANGE OF REGIONAL, CONTINENTAL, AND GLOBAL INSTITUTIONS TO FILL CLIMATE CHANGE ADAPTATION FUNCTIONS IN WEST AFRICA

Institution	Location	CC Mandate	Assess	Prioritize	Policy	Coordinate	Implement	Info
Abidjan Convention	Cote d'Ivoire	~	-	+	++	++	-	-
ECOWAS	Nigeria	+	-	~	++	++	~	~
UEMOA	Burkina Faso	~	+	~	-	-	-	~
Observatoire du Littoral Ouest Africain (OLOA)	Senegal	~	+	+	-	-	-	+
GCC/ GCLME	Ghana	~	+	~	+	++	+	+
CCLME	Senegal	~	+	~	+	++	+	+
Regional Charter and Action Plan for Sustainable Mangrove Management	Senegal	~	~	~	~	-	~	~
AGRHYMET	Niger	++	+	~	-	-	-	++
ACMAD	Niger	++	+	~	~	-	-	++
AMESD	Continental	+	+	~	~	-	-	+
AMMA	Regional	~	+	-	-	-	~	+
NEPAD	South Africa	+	-	-	-	+	-	~
IOC-GOOS	Global	+	+	-	-	-	-	+
GOOS-Africa	Continental	~	+	-	-	-	-	~
AMIS	Continental	~	-	-	-	-	-	+
GEO-CZCP	Global	+	+	+	-	+	-	~
WMO-GFCS	Global	++	-	~	~	+	~	+
ODINAFRICA	Continental	~	-	-	-	-	~	+
FAO	Global	+	+	~	~	~	~	+
WAMS	Continental	~	-	-	-	+	~	~

Key: -red=low capacity; ~yellow=ambiguous; +light green=some capacity; ++dark green=high capacity

Summary of Relationships to Adaptive Capacity Functions

No one institution is able to fill the core adaptive capacity functions necessary at the regional level. Thus, the development of new relationships and partnerships around coastal management and climate change is required.

Assessment: A wide variety of regional and global institutions have capacities to generate information that is relevant to climate-change impact and vulnerability assessments, but no institution alone has all the requisite information and expertise. There is no clear institution with the capacity to develop a holistic assessment, though the GCLME and CCLME are in relatively strong positions to coordinate such an assessment. Given the range of coastal issues of interest, it is important for those using vulnerability assessments to define areas where they can engage and focus the assessments on these potential areas of intervention, as opposed to undertaking broad assessments. Some elements of coastal assessments could require significant modeling and generation of new information by combining climate models with coastal processes. These efforts are likely to be costly. In addition, due to the range of data available at the regional level, it is particularly difficult to compare cross-country vulnerability, and users may have to settle for qualitative comparisons of potential impacts.

Prioritization: The role of prioritization of the issues and vulnerabilities is largely a nationally driven process; however, regional institutions like the LMEs, ECOWAS, and Abidjan Convention can facilitate these discussions. Participatory frameworks and processes for integrating qualitative and quantitative information are required to engage in effective prioritization. Regional prioritization will be challenged by varying information among locations, and the comparison of issues and responses across multiple sectors. At this level, there is a need to introduce participatory multi-stakeholder processes to consider adaptation challenges, options, and trial tools in the West African context.

Policy and Coordination: West African regional institutions are well-equipped to lead policy development and coordination. The history of the LMEs, ECOWAS, and Abidjan Convention makes these institutions well-suited to engage in this area; however, it is clear that more information is needed to elaborate on climate-change impacts and potential intervention options to assist in policy development and coordination. These institutions have a history of engagement at this level, but a lack of history of engagement on climate-change-relevant policy. There may be a need to support regional action on coastal climate change with international technical support to help identify the range of adaptation options and help develop interventions. With respect to coordination, the mechanisms established through the LMEs, ECOWAS, and the Abidjan Convention are well-suited to coordinate policy across countries. More challenging, however, will be actual implementation within countries and encouraging active collaboration between countries in implementation of activities.

Regional institutions and processes largely fill roles of prioritization and coordination, and as conduits for helping to mobilize and channel funding. There is inherent overlap in the roles of these regional institutions. These regional institutions cannot be expected to engage in assessments and direct implementation given their small staffs and primarily political and coordination roles. However, in this role, they are likely to contract to organizations to undertake assessments and implementation.

Implementation: There is a lack of strong implementation experience in the regional and international organizations highlighted above. This is partially due to the fact that implementation is often driven by local actors at the national and sub-national scale, but is also illustrative of the relatively low implementation capacity for coastal adaptation in terms of hard and soft solutions. In large part, the regional institutions identified in this assessment are most equipped to undertake prioritization, policy, and coordination elements related to coastal adaptive capacity, while continental and global institutions have the capacity to generate information and assessments for adaptation decisions to be based upon.

Implementation is the most significant gap in integrating climate change into coastal development. There is a need to cultivate national organizations in the private and public sectors to step into these roles.

Information Management: The role of information management, particularly as it relates to collecting and sharing lessons can, and should, be filled by a variety of organizations; however, to date, engagement on this information is relatively ad hoc and limited. There are a number of platforms that these projects feed into, such as the International Waters: Learning Exchange and Resource Network, but this does not yet feed into a clear adaptive learning process to support policy and implementation. Projects often have the goals of increasing regional information sharing and developing "comprehensive" databases (for example, the West Africa Regional Fisheries dashboard). Yet undertaking these activities through a project mechanism is dangerous due to the challenge of institutionalizing these roles within an organization. This is presently being observed in the LME process where the GCLME seems to be on hiatus while waiting for the next tranche of funding. Many of the databases cited in project documents have since gone offline, or perhaps never materialized. Prior to establishing these types of information databases, it is crucial to consider the incentives for long-term maintenance.

Additional research is necessary to consider how to best support adaptation learning and collecting of information on coastal management; however, collaboration with NOAA would likely generate valuable inputs, both through NOAA's work on climate services and through its international engagement in the LME processes. The global marine and coastal research institutions must do a better job of engaging with regional West African institutions through a model such as WASCAL or AMMA in order to build core research capacities within the institutions.

In the meantime, regional institutions such as ECOWAS and the Abidjan Convention should continue to convene forums for addressing specific coastal issues and their relevance to climate change. Sharing lessons on general coastal issues at the regional scale risks superficial engagement. Instead, a focus on specific coastal issues will ensure that the appropriate decision makers are present from each country and stakeholder group.

5.4.4 National Institutions

This assessment is limited in its ability to assess national institutions with the capacity to engage in coastal management and climate change adaptation activities, because of the large number of countries involved and the variety of institutions engaged in coastal management. National institutions often have limited Internet presence, and may only be known in relatively small areas of a country. The range of institutions that may be engaged in adaptation range from government/civil-service employees to private companies to academic institutions to nongovernmental organizations with specific development objectives. The full range of relevant institutions is not explored here, though a collection of national research institutions and universities with a relevance to coastal or climate-change issues is presented below.

Specific Country Priorities and Needs

Individual country profiles on climate-change needs and key government policies and reports are well documented in IISD's 2011 "Review of Current and Planned Adaptation Action: West Africa." This overview of hundreds of existing and proposed projects includes 15 current and 30 planned projects (Tables 18 and 19). For the most part, these efforts are funded and implemented through international and intergovernmental organizations with local partners. At the regional level, implementation activities primarily focus on capacity building and policy harmonization. These types of efforts will undoubtedly continue to drive regional coordination and collaboration.

TABLE 18. COASTAL ADAPTATION PROJECTS IMPLEMENTED IN WEST AFRICA AS OF 2012

	Project	Regional	Countries	Years	Funding	Implementers
1	Cities and Climate Change Initiative	Global	Senegal			
2	Managing Water in the Rural-Urban Interface: The key to Climate-Change-Resilient Cities	Continental	Ghana	2009–2012	International Development Research Center (IDRC)/Department for International Development (DFID)	International Water Management Institute (IWMI), Council for Scientific and Industrial Research (CSIR)
3	West African Science Service on Climate and Adapted Land Use (WASCAL)	Regional	Benin, Burkina Faso, Côte d'Ivoire, the Gambia, Ghana, Mali, Niger, Nigeria, Senegal, Togo	Founded 2010	German Federal Ministry of Education and Research	University of Bonn
4	Adaptation to Climate Change: Responding to Coastline Change and Its Human Dimensions in West Africa Through Integrated Coastal Area Management	Regional	Cape Verde, the Gambia, Guinea-Bissau, Mauritania, Senegal	2006–2010	GEF	UNDP/GEF, UNESCO/IOC
5	Adapting Fishing Policy to Climate Change with the Aid of Scientific and Exogenous Knowledge	Regional	Cape Verde, the Gambia, Guinea-Bissau, Mauritania, Senegal	2008–2011	Canada	IDRC
6	CapaSIDS: Capacity Building and Knowledge on Sustainable Responses to Climate Change in Small Island Sates	Regional	Cape Verde, Sao Tomé, Príncipe	2009–2012	DFID/IDRC	*Instituto de Engenharia Mecanica*
7	Protecting the Urban Community of Contonou from the Effects of Climate Change	National	Benin	2009–2012	IDRC/DFID	*Centre de Recherche et d'Expertise pour le Developpement Local*
8	Building Adaptive Capacity and Resilience to Climate Change in the Water Sector	National	Cape Verde	2009–2014	LDCF	UNDP, National Institute for Water Resources Management
9	Increased Resilience and Adaptation to Adverse Impacts of Climate Change in Guinea's Vulnerable Coastal Zone	National	Guinea	2009–2014	LDCF	UNDP
10	Mangrove Ecosystem Services and Climate Change Adaptation in Guinea-Bissau	National	Guinea-Bissau	2009–2010	Wetlands International	Wetlands International
11	Enhancing Resilience of Vulnerable Coastal Areas to Climate Change Risks	National	Liberia	2010–2014	LDCF	UNDP

	Project	Regional	Countries	Years	Funding	Implementers
12	Partnership for the Adaptation of Populations That are Vulnerable to Soil Salinity Due to Climate Change	National	Senegal	2009–2012	DFID/IDRC	Senegalese Agricultural Research Institute (ISRA)
13	Adaptation to Coastal Erosion in Vulnerable Areas	National	Senegal	2010–2014	Adaptation Fund	CSE
14	Developing a Method for Adaptive Management and Protection from Climate Change in Mangroves and Coral Reef Ecosystems	National	Cameroon	2007–2009	GEF/UNEP, WWF	WWF, Wetlands International, Institute of Applied Sciences, Wildlife Conservation Society
15	Communiy-Led Response to Climate Change Through Communication, Awareness Creation, and Education	National	Ghana	2009-2010	AfricaAdapt	People's Dialogue on Human Settlements

TABLE 19. COASTAL ADAPTATION PROJECTS PROPOSED IN NATIONAL ADAPTATION PROGRAMS OF ACTION

	Project	Regional	Countries
1	Protection of coastal areas against sea-level rise	National	Benin
2	Integrated protection and management of coastal zones	National	Cape Verde
3	Mapping of hazards and risk zones over the archipelago	National	Cape Verde
4	West African shorelines along the Canary Current	National	Cape Verde
5	Promote research on climate change impacts and vulnerability	National	Cote d'Ivoire
6	Restoration/protection of coastal environments	National	The Gambia
7	Increasing fish production through aquaculture and conservation of post-harvest fisheries products	National	The Gambia
8	Information support system for the sustainable management of the coastal zone of Ghana	National	Ghana
9	Initiation of coastal populations to the technique of mangrove oyster farming	National	Guinea
10	Promote the use of solar energy for drying fish to reduce the use of mangrove wood for smoking	National	Guinea
11	Promoting the use of solar energy in the extraction of sea salt	National	Guinea
12	Protection of the agricultural areas on the waterfront from saltwater intrusion	National	Guinea
13	Promotion of environmental education for coastal communities	National	Guinea
14	Protection of spawning grounds in the estuaries of the Fatala, Konkoure, and Mellacore	National	Guinea
15	Capacity-building in prevention and protection of saltwater rice against high-tide invasion project	National	Guinea-Bissau
16	Observatory for mangrove monitoring and evaluation	National	Guinea-Bissau
17	Coastal-areas erosion-monitoring project	National	Guinea-Bissau

	Project	Regional	Countries
18	Protection, conservation, and enhancement of fishing and coastal resources	National	Guinea-Bissau
19	Environmental education and communication on coastal areas	National	Guinea-Bissau
20	Rehabilitation of small perimeters of mangrove soils for rice growing	National	Guinea-Bissau
21	Coastal protection	National	Senegal
22	Development of an Integrated coastal zone management plan	National	Sierra Leone
23	Rehabilitation of degraded coastal habitats in the northern region	National	Sierra Leone
24	Development and enactment of appropriate policies and regulations relevant to the development of coastal communities, urban growth planning, and critical coastal ecosystems	National	Sierra Leone
25	National sea-level observing system	National	Sierra Leone
26	Permanent study program of the multi-species fisheries	National	Sierra Leone
27	Delineation and restoration of vulnerable fishing habitats	National	Sierra Leone
28	Improvement in the quality on fisheries-related data and research	National	Sierra Leone
29	Reinforcing the coastal protection system against coastal erosion	National	Togo
30	Enhancing the livelihood of gardener communities and fishermen in the coastal zone to increase their capacity to adapt	National	Togo

National Implementing Entities

In many countries, government agencies (most often agencies under the Ministry of Environment) are envisioned to be the primary implementers and managers of adaptation activities. In Senegal, the semi-autonomous *Centre Suivi d'Ecologique* (CSE) is the primary implementer of government environmental- and coastal-management priorities, and is an implementing entity of the Adaptation Fund. The Ministry of Environment of Benin is also pursuing a similar approach to becoming an implementing entity of the Adaptation Fund. These efforts are welcome, and other national implementing institutions from across the region may find value in joint training and sharing of lessons with the Benin and Senegal experiences. Nevertheless, capacities within national agencies vary. Representatives from Sierra Leone and Liberia stressed that government has little capacity implementing existing coastal-management laws and regulations (many related to the Abidjan Convention). An additional challenge is related to the cross-sectoral implementation activities required for successful adaptation. While adaptation is commonly considered politically within the Ministry of Environment, implementation of coastal activities may occur in any number of other sectors, and thus mainstreaming of climate change across ministries becomes a significant challenge in terms of implementation and in terms of developing plans for strategic support and capacity building.

Even in cases where clear civil service staff that needs to engage in climate-resilient activities can be identified, the model for training staff in climate-smart activities differs from top-down directive extension services. It is clear that a different set of skills is required to implement adaptation activities from standard development activities. Standard development and extension services deliver specific products to respond to specific problems or challenges that are well-defined. Climate change, in contrast, has a range of uncertainties associated with it, and thus requires responses that are well-adapted to a range of potential futures. The responses proposed by extension agents require the development of plausible scenarios of a future world and the development of adaptive responses. This requires a less directive and top-down definition of challenges and solutions. Integrating climate change into agency implementation may be an insurmountable challenge in the near-term, requiring targeted capacity-building of national implementers.

Relevant national implementing entities will differ depending on the challenge and intervention to be addressed. At a regional scale, it is not possible to outline every relevant government implementing entity each of the West African countries of interest.

National Academic and Research Institutions

There are a broad range of academic and research centers across West African countries working on coastal issues. However, these do not necessarily overlap with research centers with climate-change expertise. Most of these centers are underfunded and have limited staff to contribute to regional coastal and climate-change assessments. Because climate change expertise has largely focused on responding to Sahelian challenges, there are few climate-change experts (let alone institutions) in the region with a focus on coastal issues. Coastal research centers are more developed, and a number of centers of excellence have been established related to the Abidjan Convention. However, at the moment, none have an explicit climate-change focus. There may be value in developing more explicit efforts to link existing climate expertise (for example, through AMMA and ACMAD) to coastal zone issues and processes.

TABLE 20. LIST OF EXPERT INSTITUTIONS IDENTIFIED IN DATABASE OF MARINE AND FRESHWATER PROFESSIONALS AND THROUGH THE OCEANOGRAPHIC INFORMATION DATA EXCHANGE (IODE) AND WWW.OCEANEXPERT.NET

Country	Institution
Benin	Benin Oceanographic and Fisheries Research Center
Cameroon	National Oceanographic Data Center
Cameroon	University of Buea, Faculty of Science
Cameroon	Institute of Agricultural Research for Development
Cape Verde	None
Côte d'Ivoire	*Centre National de Recherches Oceanologiques*–Abidjan
Côte d'Ivoire	University of Ivory Coast, Laboratory of Physics of Atmosphere and Fluid Mechanics
Côte d'Ivoire	*Université de Cocody Abidjan, Centre Universitaire de Recherche et d'Application en Teledetection*
Ghana	Council for Scientific and Industrial Research
Ghana	Environmental Protection Agency–Ghana
Ghana	Ghana Oceanographic Data Center
Ghana	University of Ghana, Department of Oceanography and Fisheries
Ghana	University of Cape Coast
Ghana	University of Ghana-Legon
Guinea	*Centre de Recherche Scientifique de Conakry-Rogbane*
Guinea Bissau	None

Country	Institution
Liberia	None
Nigeria	Nigerian Institute for Oceanography and Marine Research
Nigeria	Federal College of Fisheries and Marine Technology, Victoria Island, Lagos
Nigeria	Federal University of Technology, Akure, Nigeria
Nigeria	Lagos State University, Department of Fisheries
Nigeria	National Maritime Administration and Safety Agency
Nigeria	University of Calabar
Senegal	*Centre de Recherche Oceanographique de Dakar Thiaroy*
Senegal	*Institute Senegalais de Recherches Agricoles*
Senegal	*Université Assane Seck de Ziguinchor*
Sierra Leone	None
The Gambia	None
Togo	University of Lome, Center of Integrated Coastal Zone Management

Civil-Society Private Sector and Communities of Practice

In many of the smaller West African countries, there is only a limited private sector capable of implementing coastal climate-resilient infrastructure or natural-resource-management projects, and in many cases, the government itself is the implementing agency for projects. In Liberia, for example, a government representative lamented that there are no local nongovernmental organizations, universities, or private-sector actors focusing on coastal issues. Nigeria, Ghana, and Senegal have strong private-sector actors who can implement activities nationally and regionally. Particularly in the area of coastal infrastructure, there may be a need to work directly with local contractors and developers on integrating climate-resilient approaches to infrastructure development.

There are a limited number of networks and communities of practice in West Africa working on climate-change issues, and none of these have a specific focus on coastal issues. These include AfricaAdapt, the Africa Partnership on Climate Change Coalition, Capacity Strengthening of Least Developed Countries for Adaptation to Climate Change, and the Climate Action Network–West Africa (IISD, 2011). Of these, AfricaAdapt is the most active group and may provide a suitable platform for communities of practice to develop; however, AfricaAdapt's current user group has a large focus on agricultural issues.

5.5 INSTITUTIONAL GAPS AND RECOMMENDATIONS

Across the region, there is a limited understanding of the role of climate change in coastal processes. There is a need to consolidate information on climate impacts on the key regional fish species, to map the relative impact of climate change in the range of coastal zone processes through causal chains, and to identify where climate is likely to be playing a significant impact and where potential interventions may help populations better adapt to climate change. This requires both an understanding of the issues and the potential responses. In terms of technical areas of engagement, this study identified the following vulnerable systems and regions:

- Urban centers and freshwater resources;

- Mangrove areas;
- Climate information and services; and
- Coastal fisheries.

Unsurprisingly, the coastal zone of West Africa has a range of regional institutions with overlapping mandates on planning and resource management, based on shared languages, ecosystems, or common challenges. While many of these institutions have adopted climate change as a particular concern/funding opportunity, none have fully integrated climate change into their work. Because the range of climate-change impacts on the coast is so varied and each institution has its respective expertise, there is no obvious single organization with the full regional mandate and capacity to lead climate-change interventions. At present, between the LME programs, Abidjan Convention, and ECOWAS, there is an adequate skill set to lead regional coordination of coastal climate-change-resilient implementation activities. These efforts will also require targeted inputs from regional information sources on climate from ACMAD, and on marine and coastal processes from the range of available data from international and national sources to ensure that efforts are locally relevant and regionally coordinated.

While this institutional structure is potentially robust, there is a distinct need to **build regional capacity for science and analysis** around coastal management and climate change in regional universities. While the WASCAL program is seeking to contribute to this goal, at the moment there is not a distinct window for coastal capacity. Support for national institutions to undertake policy-relevant research and analysis that contributes to national and regional efforts is a necessary step in building coastal capacity. In addition to building capacity on coastal planning within universities, there is a need to develop regional think tanks that can both lead in the development of policy questions and consult with government regionally to answer emerging questions. Working alongside the long-term efforts of the CCLME and the GCLME will help to institutionalize regional capacity-building efforts on climate-change information and analysis.

At the same time, **capacity-building for extension agents** is required to modify extension approaches to help coastal residents better plan for plausible solutions. This approach to extension and implementation does not rely on hard infrastructure solutions, but rather on helping agents develop scenarios with coastal populations. Agents become facilitators instead of bearers of top-down solutions.

Coastal issues have been acknowledged as central to West African development, yet most discussions in regional meetings and the literature focus on mangrove loss, coastal erosion, and impacts of climate change on fisheries. Less evident, but more pressing, are **the challenges of urban planning around coastal cities and access to freshwater**. While evidence of saltwater intrusion and limited surface water was found in this study, no clear evidence of climate and human-use impacts on coastal freshwater was found. Some of this data undoubtedly lies in the national and municipal water departments, but it is not clear whether the impacts of climate have been fully considered in these engineering efforts.

There are distinct opportunities for **building climate services into coastal zone planning**, which has not occurred to date. Regionally, climate services have largely focused on the Sahel, though the population of West Africa is heavily concentrated on the coasts. Investment in climate services has the potential to link climate data from ACMAD to coastal research institutions through innovative collaborations. This could also serve to build deeper relationships among coastal research institutions. The linking of oceanographic data and climate data to produce useful climate services for coastal populations is a new frontier for this work.

The **limited pool of implementers of coastal adaptation solutions** in the region is concerning. There is a small civil society and private sector working on coastal issues. At present, national government is largely responsible for implementing activities in most countries. The development of coastal-management programs by bilateral and multilateral donors may help to pull demand for coastal-management professionals. However, there is a need to build opportunities for regional and international leaders to mentor local institutions in implementing coastal-management interventions.

6.0 RESEARCH PRIORITIES

6.1 URBAN SEA-LEVEL RISE, STORM SURGE, AND FRESHWATER PLANNING

Climate-change impacts on coastal urban centers will be substantial over the coming decades and will intersect with changing demographics and increasing wealth in these cities. The urban areas of Dakar, Banjul, Conakry, Freetown, Monrovia, Abidjan, Accra, Lome, Cotonou, and Lagos are particularly vulnerable to a range of threats both related to storm surges on beach and coastal infrastructure and to flooding and water management in coastal lagoons. Urbanization is a central topic across West African development literature, and there is a need to ensure that climate change is being considered and integrated into planning processes and decisions. Because the most pressing development challenges are focused on providing basic services to existing populations and new migrants and resolving conflict and tenure issues, there is a relatively high chance that long-term climate-change-adaptation planning is not occurring. Furthermore, the relationship between urban/local government and national planning at the ministerial level provides interesting examples of how to coordinate between different levels of government.

ICLEI-Local Governments for Sustainability is helping to advance global studies on urban climate risk and integration into adaptation planning. Cross-sectoral urban vulnerability assessments are necessary as a precursor to integrating climate into urban planning, and there are emerging frameworks for better understanding urban risk to climate change (Merotra et al., 2009; Schauser et al., 2011). There are examples of urban vulnerability assessments in Lagos (Adelekan, 2009), Dakar (Schmidt, 2011), the Gambia and Abidjan (Jallow et al., 1999), Accra (Rain et al., 2001), and Cotonou (Dossou and Glehouenou-Dossou, 2007). The application of a standard vulnerability assessment framework across each of these urban centers that also has opportunities for city-specific analysis would be a valuable learning process and resource for West African coastal development. Such an assessment should examine biophysical risks as well as institutional elements that influence successful adaptation. These lessons could be shared through a regional cities forum that could more broadly look at specific urbanization challenges.

The development and application of a coastal urban vulnerability assessment could be achieved cost-effectively. Projected biophysical impacts of climate change could be performed regionally or by international partners.

Rough Level of Effort:

- Methodology development: 15 days LOE
- Urban climate impact modeling: 45 days LOE
- National/municipal institutional assessments: 50–80 days LOE each for 10 cities
- Regional workshop on urban adaptation: $150,000–200,000

Total cost per city: $40,000–75,000

6.1.1 Mangroves for Mitigation and Adaptation

West Africa hosts almost 20 percent of the world's mangroves, with the highest occurrence in Nigeria, Guinea-Bissau, Guinea, and Cameroon (Table 21). The coastal region is experiencing high population growth, poor governance, and open-access coastal resources. Mangroves are particularly vulnerable to these social and ecological trends affecting the region, and climate change is an added stress (UNEP, 2007). There is a limited understanding of how sea-level rise will impact mangrove systems and their ability to migrate and adapt as an ecosystem, or the role of mangroves as a system that contributes to adaptive capacity of coastal populations. Mangroves also have the potential to play an important role in sequestering carbon, as they have carbon-production rates equivalent to tropical humid forests (Alongi, 2012). A current USAID project, the Sustainable Wetlands Adaptation and Mitigation Program, is developing tools to better understand carbon dynamics and coastal-management options for conserving tropical wetland forests.

Wetlands International has been the most active institution regionally on mangrove management, and it is actively attempting to identify and map wetland ecosystems regionally to feed information on coastal wetland resources into decision-making processes. Regional effort could support the implementation of the Mangrove Charter and National Action Plan for West Africa by supporting efforts to restore and conserve mangrove belts. Regional collaboration could also be achieved through work with the FAO on sustainable fuel production in coastal zones for salting and smoking fish. Building on the Mangroves for Coastal Resilience work of Wetlands International, collaboration on West African mangroves could seek to identify investment opportunities for mangrove-based coastal defense strategies, as well as introducing mangrove-friendly aquaculture practices in the region, and exploring opportunities to expand the Mangrove Charter south and east of Guinea. This work would convene a group of regional and international mangrove and coastal-defense experts to develop a research and implementation agenda for understanding opportunities to support the expansion of mangroves in the face of climate change in West Africa.

Rough Level of Effort

- Background assessment on West African mangrove-expansion opportunities (in collaboration with ongoing Wetlands International work): 40 days LOE
- Prioritization of key areas for expansion through stakeholder-participation workshops and regional assessment: 40 days LOE
- Regional workshop on prioritization: $100,000
- Implementation: Dependent on size and scale of restoration

Total cost: ~$250,000

TABLE 21. COASTAL WETLANDS OF WEST AFRICA

Coastal Wetlands	Country	Area	Coastal Wetlands	Country	Area
Senegal River Floodplain	Senegal	1287 km^2	Amansuri Wetlands	Ghana	137 km^2
Senegal River Delta Complex	Senegal		Ankwao River	Ghana	
Saloum River and Delta	Senegal		Cape Three Points to Takoradi	Ghana	
Gambia River Floodplains	Senegal		Krobu River	Ghana	

Coastal Wetlands	Country	Area
Casamance Estuary	Senegal	
Minor Coastal Wetlands	Senegal	
Coastal Wetlands	Gambia	581 km^2
Swamps and Marshes of the Gambia River	Gambia	
Coastal Swamp Forests	Guinea-Bissau	2999 km^2
Interior Wetlands	Guinea-Bissau	
Coastal Wetlands	Guinea	2039 km^2
Coastal Wetlands	Sierra Leone	1052 km^2
Mano River	Liberia	110 km^2
Lake Piso	Liberia	
Lofa River	Liberia	
St. Paul River	Liberia	
Bassa Bwa Lagoon	Liberia	
St. John River	Liberia	
Cestos River	Liberia	
Sehnkwehn River	Liberia	
Cavalla River	Liberia	
Ebrie Lagoon Complex	Cote d'Ivoire	99 km^2
Tadio Lagoon Complex	Cote d'Ivoire	
Aby Lagoon Complex	Cote d'Ivoire	
Petit Digoue Lagoon	Cote d'Ivoire	
Digoue Lagoon	Cote d'Ivoire	
Katibo Lagoon	Cote d'Ivoire	
Fresco Lagoon	Cote d'Ivoire	
Heb and Kodioboue Lagoon	Cote d'Ivoire	
Cavally and Sassandra Rivers	Cote d'Ivoire	
Bandama River	Cote d'Ivoire	
Komoe River	Cote d'Ivoire	
Gbanhala, Baoule and Bagoe Rivers	Cote d'Ivoire	

Coastal Wetlands	Country	Area
Amisa River	Ghana	
Nakwa River	Ghana	
Sumina and Apabaka Lagoon	Ghana	
Winneba Wetlands	Ghana	
Accra District Wetlands	Ghana	
Volta Delta	Ghana	
Mono River	Togo	11 km^2
Oti River	Togo	
Coastal Lagoon	Benin	66 km^2
Mono River	Benin	
Oueme Delta	Benin	
Niger River	Benin	
Pendjari River	Benin	
Lagos and Lekki Lagoons	Nigeria	7386 km^2
Niger Delta	Nigeria	
Cross River	Nigeria	
Coastal Plain	Cameroon	1957 km^2
Tidal Swamp	Cameroon	

6.2 COASTAL CLIMATE SERVICE INNOVATION PARTNERSHIP

Climate services are not well-developed for coastal-zone issues. Globally, early-warning systems for coastal disasters do exist, such as well-developed tsunami early-warning systems for ocean basins, and some regional coastal flooding systems, primarily in developed countries. West Africa provides an interesting laboratory for exploring the role of coastal climate services and piloting delivery of services across a variety of countries.

One of the primary challenges of climate services is reaching affected populations. Different West African countries will have different approaches for providing information to their coastal communities and engagement. This provides an interesting laboratory for pilot activities in a variety of countries to contrast the effectiveness of a variety of private- or public-sector-led approaches to reaching communities with coastal climate service information.

Given the role of NOAA in domestic early-warning systems and in supporting the GCLME, there may be strong opportunities for collaboration on coastal information innovations and building support to regional institutions on individual climate services. NOAA could work with regional partners on processing climate and weather information and defining a selection of potentially valuable climate services and affected populations. Such work could feed into USAID support for the SERVIR program, or its support to the Global Framework for Climate Services.

Collaboration with NOAA is a challenge worth pursuing, as it provides USAID with direct access to global observation and training programs for international meteorologists. NOAA's historical collaboration with the World Meteorological Organization, through programs such as Rainwatch, provides a model for international collaboration. However, NOAA's collaboration on Africa will require the development of strong relationships within the International Affairs Office and through demonstrating how engagement will support U.S. national efforts.

As in many federal agencies, technical expertise falls within a number of different offices. NOAA's National Ocean Service, based in Charleston, South Carolina, has a strong history in providing resources on marine sanctuaries, estuarine reserves, and broader coastal zone management. These resources could be leveraged, but require the development of relationships with USAID. Similarly, building upon the Fisheries Service engagement in the LME movement will be important to continue the strides made on the GCLME and CCLME. While there is interest and expertise within the Fisheries Service, its funding for international travel and technical services is limited. Since this has historically been driven by people who are beginning to retire, there is a need to redevelop collaboration and engagement. A final constraint to building a deeper and long-term engagement is the political movement for NOAA science funds to support IUU fishing, general fisheries management, and improved hurricane prediction.

Building engagement with NOAA on regional USAID coastal zone work is a challenge worth pursuing through travel-fund support for NOAA scientists to participate and act as scientific advisors to both USAID and West African partners on regional on coastal zone management. This arrangement could be best formalized between NOAA and USAID to take advantage of the respective skill sets of each agency, leveraging existing expertise at limited cost.

Rough Level of Effort

- Background paper on coastal early warning and relevance to climate services: 15 days LOE
- Institutional assessment of potential West Africa regional coastal climate service partnerships: 15 days LOE
- Adapting NOAA U.S. coastal climate services resources to West African context: 100 days LOE

- Development of climate service partnership with two to three regional research and implementation institutions: Dependent on the scale of engagement

Total cost: ~$100,000–250,000

6.2.1 Coastal Erosion and Coastal Infrastructure

The relative importance of climate change in coastal erosion processes is poorly understood. Erosion is a crucial issue in coastal development, and UEMOA is currently addressing the science and management plans related to coastal erosion at the regional level. While USAID should remain actively engaged in the discussions of coastal erosion, and may wish to become involved in implementing activities to counter erosion, the usefulness of playing a leadership role in this process is probably limited.

6.2.2 Fisheries and Aquaculture Planning

Nearshore and marine fisheries are undoubtedly impacted by changing climate, and yet the climate impacts on particular species and ecosystems are poorly understood. Estuaries, lagoons, and shallow waters are likely to be significantly impacted at the local level, as these systems will heat more dramatically than deeper waters. As USAID and other donors invest in coastal fisheries planning and community aquaculture, primary and secondary research is necessary to catalogue the relative expected impacts of water temperature on the fish and aquaculture systems of the region. <u>Fisheries impact assessment:</u> Pure scientific research on climate-change impact on coastal fisheries in West Africa is potentially interesting, but should likely be done through active collaboration with NOAA, which is already considering these applied research questions on various fisheries around the world.

Individual species experts at different regional universities could be supported in this work; however, for many of the species, there will be insufficient data to draw strong actionable conclusions.

Aquaculture planning will be particularly impacted by climate information. Basic mapping of aquaculture in West Africa has been performed by the FAO, and this work and analysis could be supplemented by projecting potential water-temperature changes and assessing their impact on these systems. Climate-resilient community aquaculture has been explored internationally, and elements of this work could be brought into future USAID coastal-zone investments. Deeper research on this topic could be undertaken by an international aquaculture expert leading a team of national researchers in countries with significant or growing aquaculture interests.

A basic methodology could be developed to guide each of the country nearshore fisheries and aquaculture assessments, with water temperature and climate-impact models performed through a regional institution, such as ACMAD, or through ACMAD collaboration with national universities.

Rough Level of Effort

- Methodology development for West Africa: ~10 days LOE
- Climate/water modeling: ~10 days LOE to establish method/system and ~5 days per country
- National application of methodology: $7,000–20,000 per country, depending on the use of international methodology leader
- Regional workshop on coastal aquaculture and climate change: $20,000–50,000, depending on size/topics, etc.

Total five-country assessment cost: $90,000–195,000

7.0 REFERENCES

Addo, K.A., Larbi, L., Amisigo, B., Ofori-Danson, P.K. (2011). Impacts of coastal inundation due to climate change in a CLUSTER of urban coastal communities in Ghana, West Africa. Remote Sensing, 3:2029-2050

Adegoke, J.O., Fageja, M., James, G., Agbaje, G., Ologunorisa, T.E. (2010). An assessment of recent changes in the Niger Delta coastline using satellite imagery. Journal of Sustainable Development 3. Retrieved from http://www.ccsenet.org/journal/index.php/jsd/article/view/8558

Adekolaa, O., Mitchella, G. (2011). The Niger Delta wetlands: threats to ecosystem services, their importance to dependent communities and possible management measures. International Journal of Biodiversity Science, Ecosystem Services & Management, 7:50-68.

Adelekan, I.O. (2009). Vulnerability of poor urban coastal communities to climate change in Lagos, Nigeria. Presented at the Fifth Urban Research Symposium 2009. Retrieved from http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1256566800920/6505269-1268260567624/Adelekan.pdf

African Development Bank Group (AfDB), the African Union Commission (AUC), and the United Nations Economic Commission for Africa (UNECA) (2012). African statistical yearbook. Tunis and Addis Ababa: African Development Bank Group (AfDB), the African Union Commission (AUC) and the United Nations Economic Commission for Africa (UNECA).

Akouvi, A., Dray, M., Violette, S., de Marsily, G., and Zuppi, G.M. (2008). The sedimentary coastal basin of Togo: example of a multilateral aquifer still influenced by a palaeo-seawater intrusion. Hydrogeology Journal, 16(3):419-436.

Alongi, D. (2012). Carbon sequestration in mangrove forests. Carbon Management, 3(3):313-322.

Anthony, E.J. (2004). Sediment dynamics and morphological stability of estuarine mangrove swamps in Sherbro Bay, West Africa. Marine Geology, 208:207-224.

Appiah, E. B. (2005). The Encyclopedia of the African and African American Experience. Oxford University Press, 2005.

Asimiea, O.A. (2011). The effect of climate change on the Nigerian coastline: a case study of the Niger Delta. International Journal of Advanced Biotechnology and Research, 2:291-295. Retrieved from http://www.bipublication.com

Awosika, L.F., French, G.T., Nicholls, R.T., and Ibe, C.E., (1992). The impacts of sea level rise on the coastline of Nigeria [O'Callahan, J. (ed.)]. Global Climate Change and the Rising Challenge of the Sea. Proceedings of the IPCC Workshop at Margarita Island, Venezuela, 9-13 March, 1992. National Oceanic and Atmospheric Administration, Silver Spring, MD, USA, 690 pp.

Badjeck, M-C., Allison, E.H., Halls, A.S., Dulvy, N.K. (2010). Impacts of climate variability and change on fishery-based livelihoods. Marine Policy, 34:375-383.

BGR-GSD (2006). Ghana-Germany Technical Cooperation: Environmental and Engineering Geology for Urban Planning in the Accra-Tema Area, 2003-2006. Technical Reports and Maps, CDROM, Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) and Ghana Survey Department (GSD).

Binet, D., Gobert, B., Maloueki, L. (2001). El Niño-like warm events in the eastern Atlantic and fish availability from Congo to Angola Aquatic Living Resources, 14:99-113.

Bodin N, N'Gom Ka R, Le Loc'h F, Raffray J, Budzinski H, Peluhet L, Tito de Morais L.L. (2011). Are exploited mangrove molluscs exposed to persistent organic pollutant contamination in Senegal, West Africa. Chemosphere, 84:318-327.

Boko, M. I.-E. (2007). Africa. Climate Change 2007: Impacts, Adaptation and Vulnerability. Cambridge University Press.

Bormann, H. (2005). Regional hydrological modeling in Benin (West Africa): Uncertainty issues versus scenarios of expected future environmental change. Physics and Chemistry of the Earth, Parts A/B/C 30:472-484.

Brander, K. (2009). Impacts of climate change on fisheries. Journal of Marine Systems. In press, doi:10.1016/j.jmarsys.2008.12.015.

Brashares, J., Arcese, P., Sam, M., Coppolillo, P., Sinclair, A., Balmford, A. (2004). Bushmeat hunting, wildlife declines, and fish supply in West Africa. Science 306:1180-1183.

CEDA (2007). Rapport National sur l'Environnement Marin et Côtier du Bénin. Retrieved from http://abidjanconvention.org/media/documents/coast_reports/Rapport_PNUE_Draft_FINAL.pdf

Chapman, P.M. (2012). Management of coastal lagoons under climate change. Estuarine, Coastal and Shelf Science, 110:32-35.

Cheung, W.W.L., Lam, V.W.Y., Sarmiento, J.L., Kearney, K., Watson, R., Pauly, D. (2009). Projecting global marine biodiversity impacts under climate change scenario. Fish and Fisheries, doi:10.1111/j.1467-2979.2008.00315.x.

CIA. (2011). CIA World Factbook. Retrieved from https://www.cia.gov/library/publications/the-world-factbook/

CIA. (2009). CIA World Factbook. Retrieved from https://www.cia.gov/library/publications/the-world-factbook/

Conchedda, G., Lambin, E.F., Mayaux, P. (2011). Between land and sea: livelihoods and environmental changes in mangrove ecosystems of Senegal. Annals of the Association of American Geographers, 101:1259-1284

Convention on the Wetlands. (1971). Ramsar, Iran. Article 1.1.

Cornelissen, T., Diekkrüger, B., Giertz, S. (2013). A comparison of hydrological models for assessing the impact of land use and climate change on discharge in a tropical catchment. Journal of Hydrology, 498:221-236.

Coulthard, S. (2008). Adapting to environmental change in artisanal fisheries: Insights from a South Indian Lagoon. Global Environmental Change, 18:479-489.

Crawford, O.B. (2008). Assessing the security implications of climate change for West Africa: country case studies of Ghana and Burkina Faso. Winnipeg, Manitoba: Internaitional Institute for Sustainable Development.

Dasgupta, S., Laplante, B., Murray, S., Wheeler, D. (2009). Climate change and the future impacts of storm-surge disasters in developing countries. CGD Working Paper 182, Center for Global Development. http://www.cgdev.org/content/publications/detail/1422836, Washington, D.C.

Defeo, O., McLachlan, A., Schoeman, D.S., Schlacher, T.A., Dugan, J., Jones, A., Lastra, M., Scapini, F. (2009). Threats to sandy beach ecosystems: A review. Estuarine, Coastal and Shelf Science, 81:1-12.

deGraft-Johnson, K.A.A., Blay, J., Nunoo, F.K.E., Amankwah, C.C. (2010). Biodiversity threats assessment of the western region of Ghana: The Integrated Coastal and Fisheries Governance (ICFG) Initiative Ghana, USAID, Coastal Resources Center University of Rhode Island.

Dennis, K.C., Niang-Diop, I., and Nicholls, R.J. (1995). Sea-level rise and Senegal: potential impacts and consequences. J. Coastal Res., special issue 14, 243-261.

Diaw; A.T. (1997). Evolution des milieux littoraux du Sénégal: Géomorphologie et Télédétection Université de Paris, I.

Dieye, E.H.B., Diaw, A.T., Sané, T., Ndour, N. (2013). Dynamique de la mangrove de l'estuaire du Saloum (Sénégal) entre 1972 et 2010. Cybergeo: European Journal of Geography [Online], Environment, Nature, Landscape, document 629, Online since 09 January 2013, connection on 28 July 2013. Retrieved from http://cybergeo.revues.org/25671; doi:10.4000/cybergeo.25671.

Douglas, I., Alam, K., Maghenda, M., Mcdonnell, Y., Mclean, L., Campbell, J. (2008). Unjust waters: climate change, flooding and the urban poor in Africa. Environment and Urbanization, 20:187-205.

Doussou, K., Glehouneou-Dossou, B. (2007). The vulnerability to climate change of Cotonou (Benin): the rise in sea level. Environment & Urbanization International Institute for Environment and Development, 19:65–79. Retrieved from http://eau.sagepub.com/content/19/1/65.full.pdf+html

Dow, K. (2005). Vulnerability profile of West Africa. Stockholm: Stockholm Environment Institute.

Drinkwater, K.F., Beaugrand, G., Kaeriyama, M., Kim, S., Ottersen, G., Perry, R.I., Pörtner, H-O., Polovina, J.J., Takasuka, A. (2009). On the processes linking climate to ecosystem changes. Journal of Marine Systems. In press, doi:10.1016/j.jmarsys.2008.12.014.

Ellison, J., Zouh, I. (2012). Vulnerability to climate change of mangroves: assessment from Cameroon, Central Africa. Biology, 1:617-638.

ECOWAS-SWAC/OECD (2008). Atlas on regional integrations; environment series; climate and climate change. ECOWAS-SWAC/OECD.

EM-DAT: The OFDA/CRED International Disaster Database, University Catholique de Louvain, Brussels, Belgium. Data version: v11.08. E

Erwin, K. (2009). Wetlands and global climate change: the role of wetland restoration in a changing world. Wetlands Ecology and Management, 17:71-84.

Falkenmark, M. (1989). The massive water shortage in Africa: why isn't it being addressed? Ambio. 18(2):112-18.

FAO (2005). Fisheries Issues. Contribution of aquaculture to food security. FAO Fisheries and Aquaculture Department [online]. Rome. Updated 27 May 2005. [Cited 10 October 2010]. http://www.fao.org/fishery/topic/14886/en

FAO (2010). FAOSTAT database on agriculture. Rome: Food and Agriculture Organization of the United Nations.

Fashae, O.A., Onafeso, O.D. (2011). Impact of climate change on sea level rise in Lagos, Nigeria. International Journal of Remote Sensing, 32:9811-9819.

Faye, S., Maloszewski, P., Stichler, W., Trimborn, P., Faye, S., and Gaye, C. 2005. Groundwater salinization in the Saloum (Senegal) delta aquifer: minor elements and isotopic indicators. Science of the Total Environment, 343(1-3): 243-259.

Feely, R.A. et al., (2004). Journal of Oceanography., 60, 45.

FFP, 2013; Fund for Peace website, http://ffp.statesindex.org/rankings-2013-sortable

Folack, J. ND. Natural and anthropogenic characteristics of the Cameroon coastal zone. Institute of Agricultural Research for Development (IRAD). Limbe Cameroon. Retrieved from http://s3.amazonaws.com/zanran_storage/www.nodc-cameroon.org/ContentPages/54617185.pdf

French, G.T., L.F. Awosika, and C.E. Ibe, (1995). Sea level rise and Nigeria: potential impacts and consequences. J. Coastal Res., special issue 14, 224-242.

Gilman, E.L., Ellison, J., Duke, N.C., Field, C. (2008). Threats to mangroves from climate change and adaptation options: A review. Aquatic Botany, 89:237-250.

Giresse, P. (2008). 6 Atlantic ocean circulation leakage with climatic fluctuations. Developments in Quaternary Sciences, Volume 10. Elsevier, p. 43-53.

GCLME (2006a). Coastal profile of Liberia. Guinea Current Large Marine Ecosystem Project. Retrieved from http://www.gclme.org/images/costal_profile/coastal_pprofile_liberia.pdf

GCLME (2006b). Profil environnemental de la zone littorale. Project Grand Ecosysteme Marin du Courant de Guinée. Retrieved from http://www.gclme.org/images/costal_profile/coastal_profile_guinee.pdf

GCLME (2006c). Perfil costeira da Guiné-Bissau. Guiné Projecto Atual Grande Ecossistema Marinho. Retrieved from http://www.gclme.org/images/costal_profile/coastal_profile_guinee-bissau.pdf

GCLME (2006). Coastal profile of Sierra Leone. Guinea Current Large Marine Ecosystem Project. Retrieved from http://www.gclme.org/images/costal_profile/coastal_profile_sierra_leone.pdf

GOOS (2012). Requirements for global implementation of the strategic plan for coastal GOOS. Retrieved from http://www.ioos.noaa.gov/global/final_coastal_goos_pico_report.pdf

Gordon, C. (1998). Freshwater ecosystems in West Africa: problems and overlooked potentials. American Association for the Advancement of Science (AAAS) Africa Program, Science in Africa: Emergency Water Management Issues.

Gosling, S.N. (2013). The likelihood and potential impact of future change in the large-scale climate-earth system on ecosystem services. Environmental Science & Policy, 27, Supplement 1:S15-S31.

Hamilton, S. (2010). Biogeochemical implications of climate change for tropical rivers and floodplains. Hydrobiologia, 657:19-35.

Harding, A., Palsson, G., Raballand, G., (May 2007). Port and maritime transport challenges in west and central Africa.

Hewawasam, I. (2002). Managing the marine and coastal environment of sub-Saharan Africa: strategic directions for sustainable development. World Bank, Washington, District of Columbia, pp. 57.

Hinkel, J., Brown, S., Exner, L., Nicholls, R., Vafeidis, A., Kebede, A. (2012). Sea-level rise impacts on Africa and the effects of mitigation and adaptation: an application of DIVA. Regional Environmental Change, 12:207-224.

Hiraldo, R. (2011). Climate changes in West Africa: key issues. Dakar, Senegal: Energy Environment and Development.

Hughes, R.H., Hughes, J.S. (1992). A directory of Africa wetlands. World Conservation Union, United Nations Environment Programme, World Conservation Monitoring Centre.

ICST (Ivorian Country Study Team) (1996). Vulnerability of coastal zone of Cote d'Ivoire to sea level rise and adaptation options. Report on the Cote d'Ivoire/USA Collaborative Study on Climate Change in Cote d'Ivoire.

IFPRI (2013). West African agriculture and climate change, a comprehensive analysis. Washington, D.C.: International Food Policy Research Institute.

IGCC (2010). Country investment project profiles for the implementation of the GCLME strategic action programme. Guinea Current Large Marine Ecosystem Project. Retrieved from http://www.gclme.org/images/partnership_conf_2011/conf_docs/PC-007-Country_Investment%20Profiles.pdf

IGCC (2008). Strategic Action Programme: A Programme of the Governments of the GCLME Countries. Retrieved from http://www.gclme.org/images/partnership_conf_2011/conf_docs/PC-009-Strategic%20Action%20Programme.pdf

Ige, O.E. (2011). Vegetation and climatic history of the late tertiary Niger Delta, Nigeria, based on pollen record. Research Journal of Botany, 6:21-30.

IISD (November 2011). Review of Current and Planned Adaptation Action: West Africa. Retrieved from http://www.adaptationpartnership.org

IPCC (2007). Climate Change 2007. Fourth Assessment Report (AR4).

IUCN (2010). Charter and Action Plan for Sustainable Mangrove Management in the PRCM Region: Mauritania, Senegal, the Gambia, Guinea Conakry, Guinea-Bissau, and Sierra Leone. Retrieved from http://www.ntiposoft.com/domaine_200/pdf/charte_regional_english.pdf

Iwasaki, S., Razafindrabe, B.H.N., Shaw, R. (2009). Fishery livelihoods and adaptation to climate change: a case study of Chilika lagoon, India. Mitigation and Adaptation Strategies for Global Change, 14:339-355.

Jallow, B.P., Barrow, M.K.A., and Leatherman, S.P. (1996). Vulnerability of the coastal zone of the Gambia to sea-level rise and development of response options. Climate Research, 6, 165-177.

Jallow, B.P., Toure, S., Barrow, M.M., Mathieu, A.A. (1999). Coastal zone of the Gambia and the Abidjan region in Côte d'Ivoire: Sea-level rise vulnerability, response strategies, and adaptation options. Climate Research, 12:129-136. Retrieved from http://www.int-res.com/articles/cr/12_2/c012p129.pdf

Jalloh, A., Roy-Macauley, H., Sereme, P. (2012). Major agro-ecosystems of West and Central Africa: brief description, species richness, management, environmental limitations, and concerns. Agriculture, Ecosystems & Environment, 157:5-16.

Janicot, S., Fontaine, B. (1997). Evolution saisonniere des correlations entre precipitations en Afrique guineenne et temperatures de surface de la mer (1945 a 1994). Comptes Rendus de l'Academie des Sciences–Series IIA–Earth and Planetary Science, 324:785-792.

Kamga, A.F., and Buscarlet, E. (2006). Simulation du climat de l'Afrique de l'Ouest à l'aide d'un modèle climatique régional. "La meteorology," the French Meteorological Society's newsletter.

Ketchum, B. H. (1972). The water's edge: critical problems of the coastal zone. Coastal Zone Workshop, 22 May-3 June, 1972, Woods Hole, Massachusetts. Cambridge: MIT Press.

Kim, S-Y., Scourse, J., Marret, F., Lim, D-I. (2010). A 26,000-year integrated record of marine and terrestrial environmental change off Gabon, west equatorial Africa. Palaeogeography, Palaeoclimatology, Palaeoecology, 297:428-438.

Kortatsi, B.K. (2003). The origin of high salinity waters in the Accra Plains groundwater. Prepared for the Conference on Saltwater Intrusion and Coastal Aquifers: Monitoring, Modeling and Management. Merida, Mexico, 30 March–2 April 2003. Retrieved from http://www.olemiss.edu/sciencenet/saltnet/swica1/Kortatsi-Jorgensen-paper.pdf

Kouassi, Amani Michel. Tozan Michel N'guessan, Koffi Fernand Kouamé, Kassi Alexis Kouamé, Jean-Claude Okaingni, Jean Biemi. (2012). Application de la methode des simulations croissanes a l'analyse de tendances dans la relation pluie-debit a partir du modele GR2MA: cas du bassin versant du Nâezi-Bandama (Cote d'Ivoire). Comptes Rendus Geoscience, 344:288-296.

Lam, V.W.Y., Cheung, W.W.L., Swartz, W., Sumaila, U.R. (2012). Climate change impacts on fisheries in West Africa: implications for economic, food and nutritional security. African Journal of Marine Science, 34:103-117.

Lloret, Javier, Arnaldo Marín, Lázaro Marín-Guirao. (2008). Is coastal lagoon eutrophication likely to be aggravated by global climate change? Estuarine, Coastal and Shelf Science, 78:403-412.

Ly, C.K. (1980). The role of the Akosombo Dam on the Volta river in causing coastal erosion in central and eastern Ghana (West Africa). Marine Geology, 37:323-332.

MAED (2002). Etude sur la fiscalité de la pêche en Mauritanie, Rapport provisoire, Ministère des Affaires Economiques et du Développement, Repulique Islamique de Mauritanie.

Matul, M., McCord, M., Phily, C., and Harms, J. (October 2009). The landscape of microinsurance in Africa.

Mehrotra, S., Natenzon, C.E., Omojola, A., Folorunsho, R., Gilbride, J., and Rosenzweig, C. (2009). Framework for City Climate Risk Assessment. Presented at the Fifth Urban Research Symposium 2009. Retrieved from http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1256566800920/6505269-1268260567624/Rosenzweig.pdf

Mbuh, M.J., Mayer, R, Paul, T. (2012). Assessment of the nature and the rate of coastal erosion on the mount Cameroon coastal landscape, southwest region, Cameroon. Journal of Coastal Research, 1214-1224.

McClanahan, T., Allison, E.H., Cinner, J.E. Managing fisheries for human and food security. Fish and Fisheries. In press. doi: 10.1111/faf.12045.

Mensah, K.O., and FitzGibbon, J. (2012). Responsiveness of Ada Sea Defence Project to saltwater intrusion associated with sea level rise. Journal of Coastal Conservation, 17(1):74-85.

Minist ère de l'Economie maritime des Transports maritimes, de la Pêche et de la Pisciculture. (2007). Lettre de Politique Sectorielle des Pêches et de l'Aquaculture. Retrieved from http://www.ntiposoft.com/domaine_200/pdf/lettre_de_politique_sectorielle.pdf.

Monde, S., Toure, M., N'guessan, Yao M. (2001). Recent geomorphological changes in Ebrié lagoon, Côte d'Ivoire, West Africa. International Journal of Scientific & Engineering Research, 2:1-7.

NEPAD (2005). Global Change and the New Partnership for African Development. CSIR/NRE/ECO/ER/2006/0016/C. Retrieved from http://community.eldis.org/.5994ce60/NEPAD%2520Global%2520Change%2520Final.pdf

Niang-Diop, I., Dansokho, M., Faye, S., Gueye, K., and Ndiaye, P. (2010). Impacts of climatae change on the Senegalese coastal zones: Examples of the Cap Vert Peninsula and Saloum estuary. Quaternary and Global Change, 72(4):294-301.

Niang-Diop, I. (2005). Impacts of Climate Change on the Coastal Zones of Africa. In: IOC "Coastal Zones in Sub-Saharan Africa: A scientific review of the priority issues influencing sustainability and vulnerability of coastal communities," London, May 27–28, 2003, Workshop Report 186, ICAM Dossier n°4, 27-33.

Niasse, M., Afouda, A., Amani, A. (eds) (2004). Reducing West Africa's Vulnerability to Climate Impacts on Water Resources, Wetlands and Desertification, Vol. IUCN Regional Office for West Africa.

Nicholls, R.J., and Tol, R.S.J. (2006). Impacts and responses to sea-level rise: a global analysis of the SRES scenarios over the twenty-first century. Philosophical Transactions of the Royal Society A, 364, 1073-1095.

Njock, J-C., Westlund, L . (2010). Migration, resource management and global change: Experiences from fishing communities in West and Central Africa. Marine Policy, 34:752-760.

Obiefuna, J.N., Nwilo, P.C., Atagbaza, A.O., Okolie, C.J. (2013). Spatial changes in the wetlands of Lagos/Lekki lagoons of Lagos, Nigeria. Journal of Sustainable Development, 6:123-133.

Oguntunde, P.G., Friesen, J., van de Giesen, N., Savenije, H.H.G. (2006). Hydroclimatology of the Volta River Basin in West Africa: Trends and variability from 1901 to 2002. Physics and Chemistry of the Earth, Parts A/B/C 31:1180-1188.

Orr, J.C., et al. (2005). Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. Nature 437, 681.

Oteri, A.U., and Atolagbe, F.P. (2003). Saltwater Intrusion into Coastal Aquifers in Nigeria. Prepared for the Conference on Saltwater Intrusion and Coastal Aquifers: Monitoring, Modeling and Management. Merida, Mexico, 30 March–2 April, 2003. Retrieved from http://www.olemiss.edu/sciencenet/saltnet/swica2/Oteri_ext.pdf

Oyedele, K.F., and Momoh, E.I. (2009). Evaluation of seawater intrusion in freshwater aquifers in a lagoon coast: a case study of the University of Lagos Lagoon, Akoka, Nigeria. New York Science Journal, 2(3):32-42. Retrieved from http://www.sciencepub.net/newyork/0203/04_0605_Evaluation_Seawater_ny.pdf

Pala, C. (2013). Detective work uncovers under-reported overfishing. Nature, 496 doi:10.1038/496018a.

Perry, R.I., Sumaila, U.R. (2006). Marine ecosystem variability and human community responses: The example of Ghana, West Africa. Marine Policy, 31:81-84.

Powell, N., Osbeck, M., Tan, S.B., Toan, V.C. (2011). Mangrove Restoration and Rehabilitation for Climate Change Adaptation in Vietnam, World Resources Report Case Study, Washington D.C.

Raise, D., Engstrom, R., Ludlow, C., and Antos, S. (2011). Accra, Ghana: A city vulnerable to flooding and drought-induced migration. Case study prepared for Cities and Climate Change: Global Report on Human Settlements 2011. Retrieved from http://www.unhabitat.org/downloads/docs/GRHS2011/GRHS2011CaseStudyChapter04Accra.pdf

Ramsar (2002). Wetlands: water, life, and culture. Eighth Meeting of the Conference of the Contracting Parties of the Convention on Wetlands, 8-26 November, 2002, Valencia, Spain.

Raven J. et al. (2005). Ocean Acidification Due to Increasing Atmospheric Carbon Dioxide. The Royal Society. Retrieved from http://coralreef.noaa.gov/aboutcrcp/strategy/reprioritization/wgroups/resources/climate/resources/oa_royalsociety.pdf.

Rebelo, L.M., McCartney, M., Finlayson, C. (2010). Wetlands of Sub-Saharan Africa: distribution and contribution of agriculture to livelihoods. Wetlands Ecology and Management, 18:557-572.

Sahel and West Africa Club (2006). The ecologically vulnerable zone of Sahelian countries. Atlas on Regional Integration in West Africa, SWAC/OECD.

Sarch, M-T., Allison, E.H. (2000). Fluctuating fisheries in Africa's inland waters: well-adapted livelihoods, maladapted management. Proceedings of the 10th International Conference of the Institute of Fisheries Economics and Trade, Corvallis, Oregon.

Sally Brown, A. S. (2011). Sea-Level Rise and Impacts in Africa 2000 to 2100. Southampton: University of Southampton.

Satyanarayana, B., Bhanderi, P., Debry, M.I., Maniatis, D., Fora F., Badgie, D., Jammeh, K., Vanwing, T., Farcy, C., Koedam, N., Dahdouh-Guebas, F. (2012). A Socio-Ecological Assessment Aiming at Improved Forest Resource Management and Sustainable Ecotourism Development in the Mangroves of Tanbi Wetland National Park, the Gambia, West Africa. AMBIO 41:513-526.

Schauser, I., Otto, S., Schneiderbauer, S., Harvey, A., Hodgson, N., Robrecht, H., Morchain, D., Schrander, J., Khovanskaia, M, Celikyilmaz-Aydemir, G., Prutsch, A., and McCallum, S. (2011). Urban Regions: Vulnerabilities, Vulnerability Assessments by Indicators and Adaptation Options for Climate Change Impacts. ETC/ACC Technical Paper 2010/12. Retrieved from http://acm.eionet.europa.eu/reports/ETCACC_TP_2010_12_Urban_CC_Vuln_Adapt

Schmitt, K., Albers, T., Pham, T.T., Dinh, S.C. (2013). Site-specific and integrated adaptation to climate change in the coastal mangrove zone of Soc Trang Province, Viet Nam. Journal of Coastal Conservation, 17:545-558.

Schmidt, R. (2011). Urban Flood Risk in Dakar, Senegal. World Bank Africa Disaster Risk Management. Retrieved from http://www.sts.virginia.edu/wip/research_papers/2011/Schmidt.pdf

Silliman, S., et al. (2010). Issues of sustainability of coastal groundwater resources: Benin. Sustainability (2): 2652-1675.

Sumaila, U.R., Cheung, W.W.L., Lam, V.W.Y., Pauly, D., Herrick, S. (2011). Climate change impacts on the biophysics and economics of world fisheries. Nature Climate Change, 1:449 – 456.

Thiobane, M. (ed) (no date). Changements Climatiques: Joal, Palmarin, Djifère en sursis, Vol 3. Groupe recherche Environnement et Presse, WWF.

UEMOA, IUCN (2010). Regional shoreline monitoring study and drawing up of a management scheme for the West African coastal Area, UEMOA, IUCN.

U.S. Forest Service (2011). Ghana Vulnerability and Climate Change Assessment. Washington, D.C.: USAID.

UNEP (2006). Rapport National sur l'Environment Marin et Côtier. Republique de Guinée. Retrieved from http://abidjanconvention.org/media/documents/coast_reports/Rap_Nat_MOU_Guinee_Vers_Finale.pdf

UNEP (2007). Rapport National sur l'Environment Marin et Côtier. Republique Togolaise. Retrieved from http://abidjanconvention.org/media/documents/coast_reports/Etat_cotier_vf.pdf

UNEP (2007). Mangroves of Western and Central Africa. UNEP-Regional Seas Programme/UNEP-WCMC. Retrieved from http://www.unep.org/regionalseas/publications/otherpubs/pdfs/Mangroves_of_Western_and_Central_Africa.pdf

UNESCO-IOC, UNOPS (2006). Adaptation to Climate Change: Responding to Coastline Change in its human dimensions in West Africa through Integrated Coastal Area Management (ACCC). United Nations Development Programme.

UNESCO (February 2007). Climate Change Adaptation and Water Resources Management in West Africa.

United Nations (2013). FAO: Fisheries and Aquaculture 2013. Food and Agriculture Organization.

USAID (2013). Background Paper for the ARCC West Africa Regional Climate Change Vulnerability Assessment. Washington, D.C.: USAID.

USNRC (2010). America's Climate Choices: Panel on Advancing the Science of Climate Change, Board on Atmospheric Sciences and Climate, Division on Earth and Life Studies, National Research Council of the National Academies. "7 Sea Level Rise and the Coastal Environment." Advancing the Science of Climate Change. Washington, D.C.: The National Academies Press., pp. 243–250. ISBN 978-0-309-14588-6.

Uyigue, E., Ogbeibu, A.E. (2007). Climate Change and Poverty: Sustainable Approach in the Niger Delta Region of Nigeria. Conference on the Human Dimensions of Global Environmental Change, Amsterdam, p. 17.

Van Vuuren, D.P., Smith, S.J., Riahi, K. (2010). Downscaling socioeconomic and emissions scenarios for global environmental change research: a review. WIREs Climate Change 1.

Varis, O., and Fraboulet-Jussila (2002). Water Resources Development in the Lower Senegal River Basin: Conflicting Interests, Environmental Concerns, and Policy Options, 18(2):245-260.

Warren, R., Arnell, N., Nicholls, R., Levy, P., and Price, J. (2006). Understanding the regional impacts of climate change: research report prepared for the Stern Review on the Economics of Climate Change. Tyndall Centre for Climate Change Research, Working Paper 90, University of East Anglia, Norwich, pp. 223.

Waycott, M., Duarte, C.M., Carruthers, T.J.B., Orth, R.J., Dennison, W.C., Olyarnik, S., Calladine, A., Fourqurean, J.W., Heck, K.L., Hughes, A.R., Kendrick, G.A., Kenworthy, W.J., Short, F.T., and Williams, S.L. (2009). Accelerating loss of seagrasses across the globe threatens coastal ecosystems. Proceedings of the National Academy of Sciences, 106:12377-12381.

Wolanski, E. and Cassagne, B. (2000). Salinity intrusion and rice farming in the mangrove-fringed Konkoure River delta, Guinea. Wetlands Ecology and Management, 8:29-36.

Woodworth, P., Aman, A., Aarup, T. (2007). Sea-level monitoring in Africa. African Journal of Marine Science, 29:321-330.

World Bank (2013). West Africa: Fishing Communities Restore Health to Ocean Habitats. Washington, D.C.: World Bank.

World Tourism Organization. (2011). Yearbook of Tourism Statistics, Compendium of Tourism Statistics and data files.

WWF Global (2013). Depletion of fisheries could affect millions in West Africa.

Zeeberg, J., Corten, A., Tjoe-Awie, P., Coca, J., Hamady, B. (2008). Climate modulates the effects of Sardinella aurita fisheries off Northwest Africa. Fisheries Research, 89:65-75.

ANNEX A. TABLE OF REGIONAL EXPERTS AND INSTITUTIONS

Marine and Oceanographic Experts	Country	Institution/Expertise
Zacharie Souhou	Benin	IODE, National Coordinator for Oceanographic Data Management
Christian Adje	Benin	*Centre de Recherches Halieutiques et Oceanologique du Benin,* Manager
Richard Awah Nche	Cameroon	Institute of Agricultural Research for Development (IRAD), Cameroon, National Coordinator for Marine Information Management
Jean Folack	Cameroon	Ministry of Scientific and Innovation, and IRAD
Kouassi Nadege	Côte d'Ivoire	*Centre National de Recherches Oceanologiques*, Abidjan, National Coordinator for Marine Information Management
Yacouba Sankare	Côte d'Ivoire	*Centre National de Recherches Oceanologiques,* Abidjan, National Coordinator for Oceanographic Data Management
Satigui Diakite	Guinea	*Centre de Recherche Scientifique de Conakry-Rogbane,* National Coordinator for Oceanographic Data Management
Traore Kaka	Guinea	*Centre de Recherche Scientifique de Conakry-Rogbane,* National Coordinator for Marine Information Management
Abena Asante	Ghana	Senior Fisheries Officer, National Coordinator for Marine Information Management
Hawa Yaqub	Ghana	Ghana Oceanographic Data Centre, National Coordinator for Oceanographic Data Management
Adote Blim	Togo	*Universite de Lome, Centre de Gestino Integree du Littoral et de Environnement,* National Coordinator for Oceanographic Data Management
Anis Diallo	Senegal	*Centre de Recherche Oceanographicque de Dakar,* National Coordinator for Oceanographic Data Management
Arame Ndiaye Keita	Senegal	*Direction des Peches Maritimes,* National Coordinator for Marine Information Management
Massamba Cisse	Senegal	*Institute Senegalais de Recherches Agricoles*
Regina Folorunsho	Nigeria	Nigeria Institute for Oceanography and Marine Research
James Mmuomaihe	Nigeria	Nigeria Institute for Oceanography and Marine Research
Olajide Kufoniyi	Nigeria	Member of the GOOS Africa Steering Group
Kouadio Affian	Cote d'Ivoire	University of Cocody Abidjan, Leader of GOOS-Africa Remote Sensing
George Wiafe	Ghana	University of Ghana-Legon

Marine and Oceanographic Experts	Country	Institution/Expertise
Udeme Enin	Nigeria	University of Calabar, Lead Organizer of Coastal Zone and Climate Change Meeting
Mangrove Experts	**Country**	**Institution/Expertise**
Ndongo Din	Cameroon	University of Douala
Gordon Ajonina	Cameroon	Cameroon Wildlife Conservation Society
Jean Nke	Cameroon	*Defense de l'Envionnement Camrounais*
Joana Akrofo	Ghana	Division of Early Warning and Assessment, UNEP
AK Armah	Ghana	University of Ghana
Chris Gordon	Ghana	GLOMIS, University of Ghana
Elijah Ohimain	Nigeria	Environmental Microbiologist
Ayobami Salami	Nigeria	Obafemi Awolowo University
Ebeh Adayade Kodjo	Togo	*Association Nationale des Consommateurs et de l'Environnemnet*
Abilio Said	Togo	Instituto da Biodiversidade e Áreas Protegidas
Salif Diop	Regional	Division for Early Warning and Assessment

U.S. Agency for International Development
1300 Pennsylvania Avenue, NW
Washington, DC 20523
Tel: (202) 712-0000
Fax: (202) 216-3524
www.usaid.gov